WATER QUALITY MONITORING

AT F.E. WALTER RESERVOIR

DURING 2001

Prepared for

U.S. Army Corps of Engineers
Philadelphia District
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Contract No. DACW61-00-D-0009
Delivery Order No. 01

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February 2002

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1.0 INTRODUCTION

1.1 PURPOSE OF THE MONITORING PROGRAM

The U.S. Army Corps of Engineers (USACE) manages F.E. Walter Reservoir located in northeastern Pennsylvania within the Delaware River Basin. Foremost, F.E. Walter Reservoir provides flood control and a dependable water supply to downstream communities on the Lehigh River. Additionally, the reservoir provides important habitat for fish, waterfowl, and other wildlife, and recreational opportunities through fishing, and boating. Due to the broad range of uses and demands F.E. Walter Reservoir serves, the USACE monitors water quality and other aspects related to reservoir health primarily to ensure public health safety. Water quality monitoring results are compared to state water quality standards and used to diagnose other problems that commonly effect reservoir health such as nutrient enrichment and toxic loadings. This report summarizes the results of water quality monitoring at F.E. Walter Reservoir from April through October 2001. This report also discusses the relevance of the water quality measures to the ecology of the reservoir and makes recommendations toward future water quality monitoring.

1.2 DESCRIPTION OF F.E. WALTER RESERVOIR

F.E. Walter Reservoir is an integral part of the Lehigh River Flood Control Program. The authorized purpose of this project is flood control. The reservoir project was authorized as a white water project as part of Public Law 100-676, Section 6, dated November 17, 1988. Located about 9 miles southeast of Wilkes-Barre, PA, the reservoir dams a drainage area of 288 square miles. The dam can impound up to 35.8 billion gallons of floodwater. The primary surface water input into the reservoir is the Lehigh River as it flows west between Luzerne and Carbon Counties. Bear Creek, a secondary surface water input, enters the reservoir from the north. Tobyhanna Creek drains an area to the southeast and joins the Lehigh River near the headwaters of the reservoir. The reservoir is approximately 3 miles long and about 50 feet deep at the face of the dam. Average annual discharge from the dam into the Lehigh River is approximately 625 cubic feet per second (USGS 1993).

1.3 ELEMENTS OF THE STUDY

The USACE, Philadelphia District, has been monitoring the water quality of F.E. Walter Reservoir since 1975. Over this time, the yearly monitoring designs have evolved to address newly defined problems such as health of public drinking water and contamination of sediments. The 2001 monitoring program follows that in recent years and includes the following major elements:

- Monthly water quality and bacteria monitoring from April through October to evaluate compliance with the Pennsylvania state water quality standards;
- In an effort to coordinate concurrent studies, additional parameters were collected and analyzed in conjunction with the Lehigh Water Quality Study. This included the addition of a meteorological station on the dam tower;
- Sediment priority pollutant monitoring of semivolatile organics and metals to evaluate sediment toxicity relative to identified screening concentrations; and
- Drinking water monitoring to ensure public health safety by comparing water quality from a drinking water source to standards determined by the Safe Drinking Water Act (SDWA).

2.0 METHODS

2.1 PHYSICAL STRATIFICATION MONITORING

Physical stratification monitoring of the water column of F.E. Walter Reservoir was conducted seven times during 2001, between April and October (Table 2-1). Physical stratification parameters included temperature, dissolved oxygen (DO), percent of DO saturation (dependent on temperature), pH, and conductivity. Monitoring was conducted at seven fixed stations located throughout the reservoir watershed (Fig. 2-1). Surface water quality was monitored at stations downstream of the reservoir (WA-1), and upstream on Tobyhanna Creek (WA-3), the Lehigh River (WA-4), and Bear Creek (WA-5). Stratification monitoring was conducted at the reservoir-body station WA-2 with water quality measured at the surface to the bottom at 5-ft intervals. Two new stations were added this year on Bear Creek (WA-6) and on Lehigh River (WA-7). All of the water quality monitoring was conducted with a calibrated Hydrolab water quality meter.

In this report, water quality data recorded from stratification monitoring were compared to water quality standards mandated by the Pennsylvania Department of Environmental Protection (PADEP Chapter 93). The standard for DO is a minimum concentration of 5 mg/L, and that for pH is an acceptable range from 6 to 9.

All of the water quality data collected during physical stratification monitoring are summarized in Appendix Table A-1.

2.2 WATER COLUMN CHEMISTRY MONITORING

Water column chemistry monitoring was conducted seven times at F.E. Walter Reservoir between April and October (Table 2-1). Water samples were collected at the seven fixed stations throughout the reservoir drainage area (Fig. 2-1). Surface water samples were collected at stations downstream of the reservoir (WA-1) and upstream on Tobyhanna Creek (WA-3), the Lehigh River (WA-4), and Bear Creek (WA-5). Surface, middle, and bottom water samples were collected at the reservoir-body station WA-2, WA-6, and WA-7. Surface water samples were collected by opening the sample containers approximately 1 foot below the water's surface. Middle and bottom samples were collected with a Van Dorn design horizontal water bottle.

Water samples collected from surface, middle, and bottom depths were analyzed for ammonia, nitrite, nitrate, total Kjeldahl nitrogen (TKN), total phosphorus, total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD), alkalinity, total organic carbon (TOC), total inorganic carbon (TIC) and chlorophyll *a*. Table 2-2 summarizes the water quality parameters; laboratory method detection limits, state water quality standards, and allowable and achieved maximum hold times for each. Parameters such as BOD went beyond the maximum holding time by one day.

Table 2-1. F.E. Walter Reservoir water quality monitoring schedule for 2001

Date of Sample Collection	Physical Stratification Monitoring (All Stations)	Water Column Chemistry Monitoring (All Stations)	Trophic State Determination (WA-2)	Coliform Bacteria Monitoring (All Stations)	Sediment Priority Pollutant Monitoring (WA-2)	Drinking Water Monitoring*
24 April	X	X	X	X		
23 May	X	X	X	X		
13 June	X	X	X	X		Sets A and B
21 June						Total Coliform/ E. Coli
18 July	X	X	X	X	X	
9 August	X	X	X	X		Sets A
27 September	X	X	X	X		
23 October	X	X	X	X		

* Set A – comprised analyses of nitrate, nitrite, and coliform bacteria contaminants.
  Set B – comprised analyses for primary and secondary contaminants.

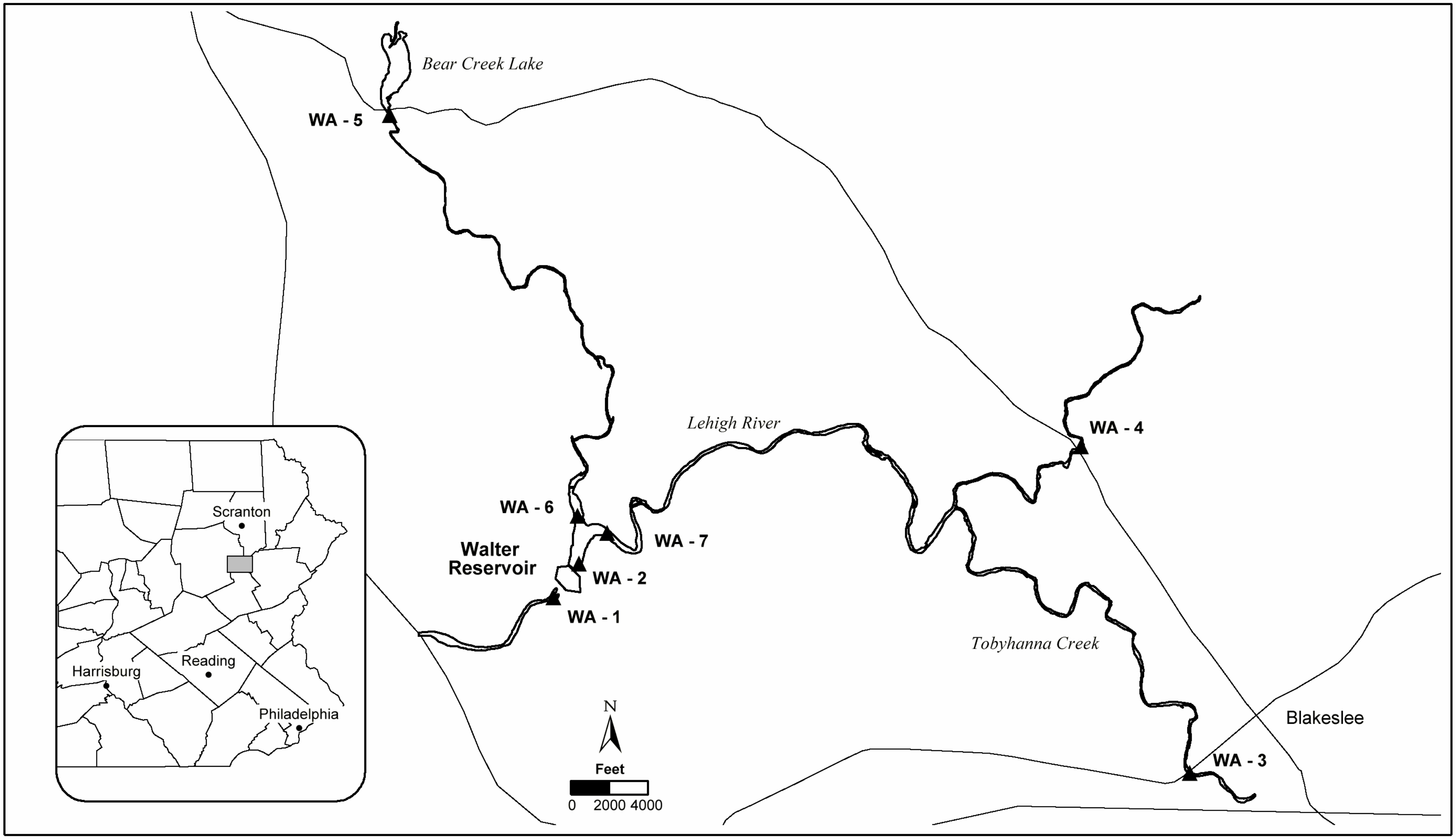

Figure 2-1 Location map for F.E. Walter Reservoir and water quality monitoring stations in 2001

Table 2-2. Water quality test methods, detection limits, state regulatory criteria, and sample holding times for water quality parameters monitored at F.E. Walter Reservoir in 2001

Parameter	EPA Method	Detection Limit	PADEP Surface Water Quality Criteria	Allowable Hold Times (Days)	Maximum Hold Time Achieved (Days)
Alkalinity	310.3	1 mg/L	minimum 20 mg/L $CaCO_3$	14	13
Biochemical Oxygen Demand (BOD)	SM5210B	3 mg/L	None	2	3
Total Phosphorus	365.2	0.05 mg/L	None	28	9
Dissolved Phosphorus	365.2	0.05mg/L	None	28	13
Dissolved Phosphate	365.2	0.05 mg/L	None	28	13
Total Organic Carbon	415.1	5 mg/L	None	28	21
Total Inorganic Carbon	415.1	5 mg/L	None	28	21
* Chlorophyll *a*	445.0	0-mg/m^3	None	90	60
Total Kjeldahl Nitrogen	351.3	0.20 mg/L	None	28	15
Ammonia	350.3	0.1 mg/L	Temperature and pH dependent	28	14
Nitrate	300	0.5 mg/L	Maximum 10 mg/L (nitrate + nitrite)	2	2
Nitrite	300	0.5 mg/L		2	2
Total Dissolved Solids	160.1	10 mg/L	Maximum 500 mg/L	7	7
Total Suspended Solids	160.2	1 mg/L	None	7	7

* Chlorophyll *a* samples were allowed this holding time when wrapped tightly in the dark at –20 °C

2.3 TROPHIC STATE DETERMINATION

The trophic state of F.E. Walter Reservoir was determined by methods outlined by Carlson (1977). In general, this method calculates trophic state indices (TSIs) independently for total phosphorus and chlorophyll *a* concentrations, and secchi disk depth. Surface water measures of total phosphorus and chlorophyll *a* from chemistry monitoring were averaged in determining monthly TSI values. Secchi disk depth was measured only in surface waters at the reservoir-body station (WA-2). Trophic state determinations were made using criteria defined by Carlson (1977) and EPA (1983).

2.4 RESERVOIR BACTERIA MONITORING

Monitoring for coliform bacteria contaminants was conducted seven times between April and October at F.E. Walter Reservoir. Surface water samples were collected in the same manner as for chemical parameter samples, and analyzed for total and fecal coliform bacteria contamination. Table 2-3 presents the test methods, detection limits, PADEP standards, and sample holding times for the bacteria parameters monitored at F.E. Walter Reservoir in 2001. The bacteria analytical method was based on a membrane filtration technique. All of the samples were analyzed within their maximum allowable hold times. At the end of the monitoring period, streamflow data (CFS) collected from USGS gauging stations in the region (Blakeslee and Stoddartsville) and precipitation data collected at the dam were used to correlate rainfall patterns with measured bacteria levels (see Section 2.5).

Table 2-3. Water quality test methods, detection limits, PADEP water quality standards, and sample holding times for bacteria parameters monitored at F.E. Walter Reservoir in 2001

Parameter	Total coliform	Fecal coliform
Test method	SM 9222B	SM9222D
Detection limit	10 clns/100-mls	10 clns/100-ml
PADEP standard	-	Geometric mean less than 200 clns/100-ml (application of this standard is conservative because swimming is not permitted in the reservoir)
Maximum allowable holding time	30 hours	30 hours
Achieved holding time	< 30 hours	< 30 hours

Monthly coliform bacteria counts were compared to the PADEP water quality standard for bacteria. The standard is defined as a maximum geometric mean of 200 colonies/100-ml based on five samples collected on different days. Given our logistical limitations (all monthly sampling conducted on one day), we calculated the geometric mean based on all of the surface samples collected for each month. Although our sampling design does not fully meet PADEP guidelines, we feel that this interpretation of the coliform data meets the intent of the PADEP water quality standard for evaluating F.E. Walter Reservoir bacteria levels. Additionally, application of this standard is conservative because swimming and other human/water contact recreation is prohibited in the reservoir.

2.5 STREAMFLOW AND PRECIPITATION DATA

Streamflow and precipitation data for the principal monitoring months from April to October were compiled from USACE records (Figs. 2-2 through 2-8). Streamflow data were collected from the USGS stations located in Blakeslee and Stoddartsville and reflect rainfall patterns throughout the F.E. Walter Reservoir watershed. Precipitation data was collected by F.E. Walter Reservoir personnel and reflects a more local condition of rainfall pattern.

In April through the middle of May, stream flow slowly decreased from over 1,000-cfs to 300-cfs until two small precipitation events took place at the end of May (Fig. 2-2 and Fig. 2-8). These rain events increased the flow to 600-cfs. After the May rain events, stream flow decreased again to 300-cfs until the middle of June when there was another rain event of over 3 inches. Monthly monitoring in all three months took place when stream flow ranged from 200 to 600-cfs. In the later part of the summer the stream flow decreased to approximately 200-cfs. Monthly monitoring was done at 200-cfs during July and August. Towards the end of September there was a storm event that exceeded 2.0 inches of rain. Monthly monitoring was conducted at a stream flow of approximately 300-cfs on September 25.

2.6 SEDIMENT PRIORITY POLLUTANT MONITORING

Sediment from F.E. Walter Reservoir was monitored for priority pollutant contaminants, Group 2 – metals and semivolatiles. Sediment was collected on 18 July at station WA-2 with a petite ponar grab-sampler. Sediment from the grab-sampler was emptied into a stainless steel mixing bowl and homogenized with a stainless steel spoon. Sediments were contained in appropriately labeled sample jars and stored on ice until shipment to the analytical laboratory. All field equipment used during the handling of reservoir sediments was decontaminated prior to sampling. Decontamination procedures were as follows: detergent wash, first deionized water rinse, 10% nitric acid rinse, second deionized water rinse, hexane rinse, and third deionized water rinse. Table 2-4 summarizes the parameters monitored, method detection limits, sample hold times, and the laboratory methods used in the analyses.

All sediment contaminant concentrations were reported on a dry weight basis, and were calculated as follows:

$$\text{Dry weight concentration (mg/kg)} = \frac{\text{Wet weight concentration (mg/kg)} \times 100}{\text{\% solid of sample}}$$

Sample-specific detection limits were calculated for the sediment tests because of matrix interference and the conversion from wet weight to dry weight.

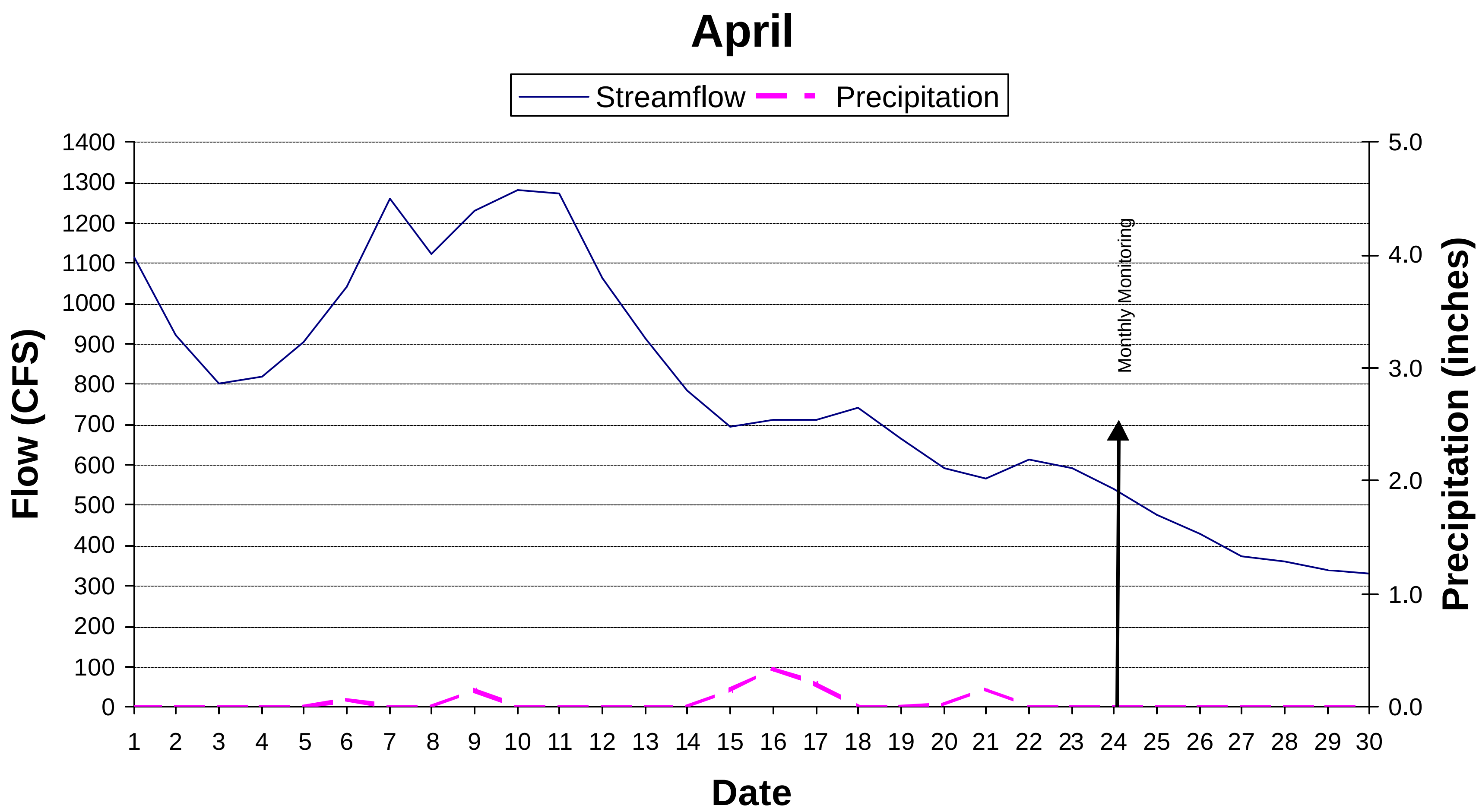

Figure 2-2. April streamflow and precipitation in the vicinity of F.E. Walter Reservoir in 2001

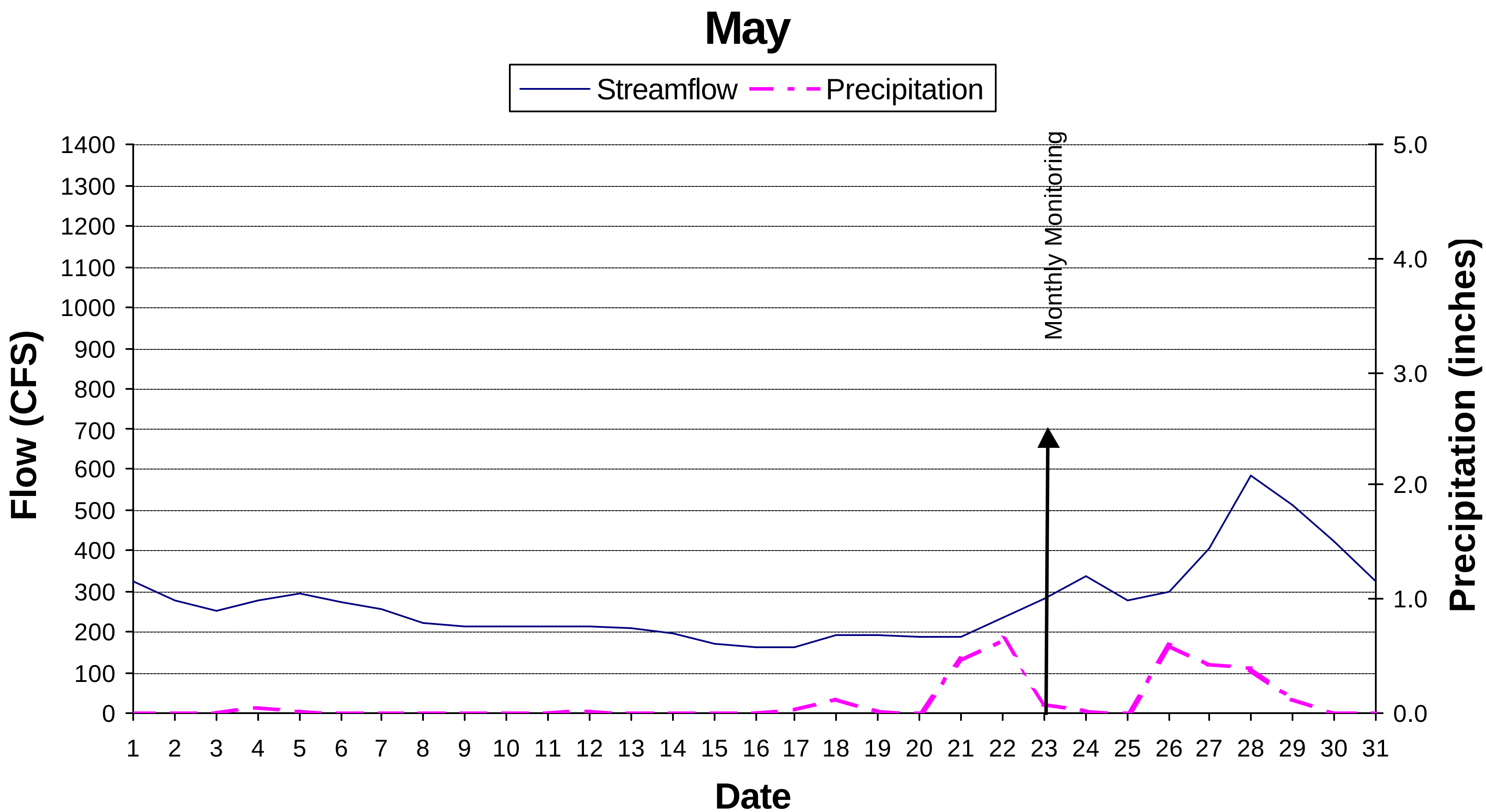

Figure 2-3. May streamflow and precipitation in the vicinity of F.E. Walter Reservoir in 2001

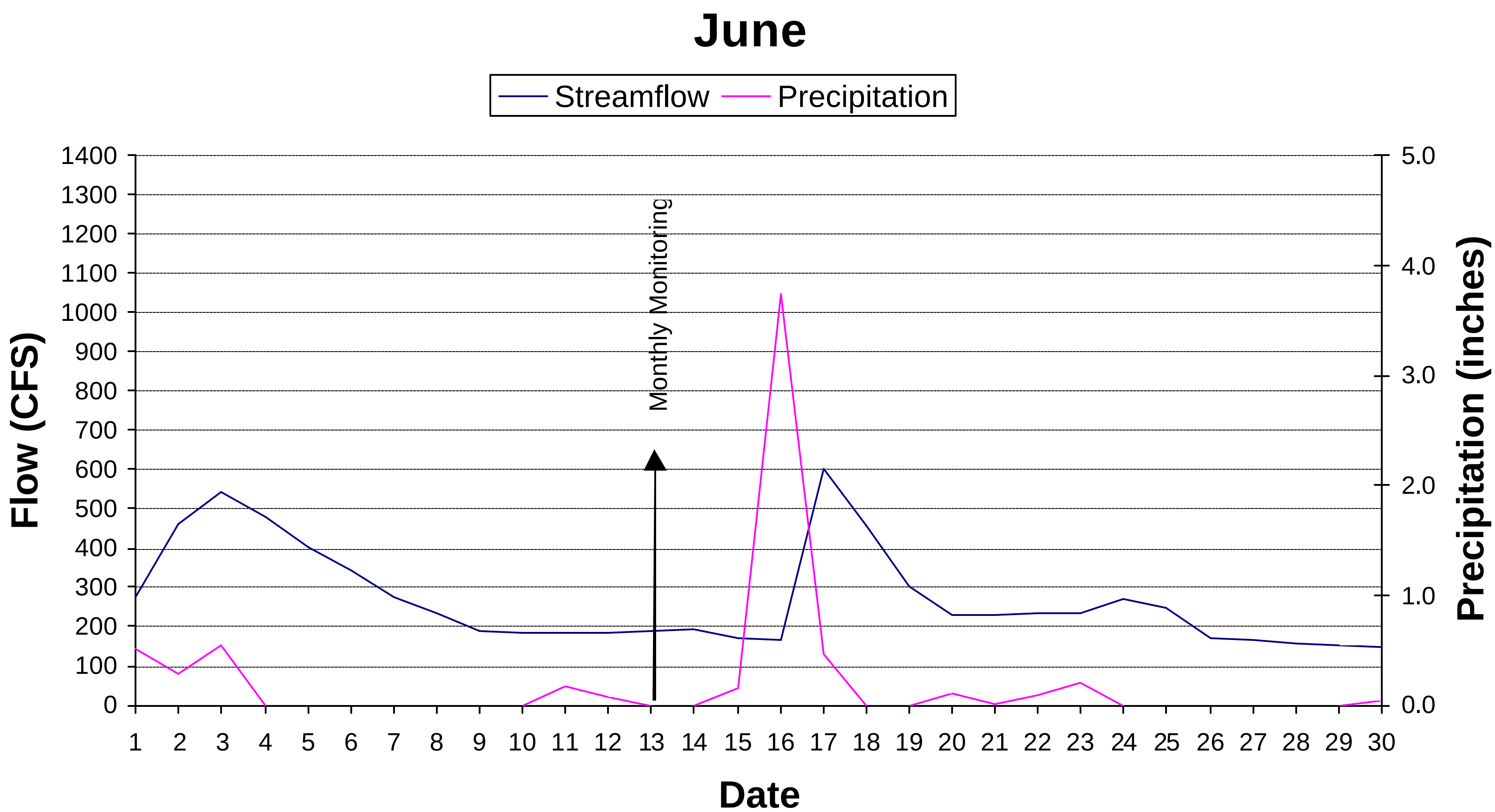

Figure 2-4. June streamflow and precipitation in the vicinity of F.E. Walter Reservoir in 2001

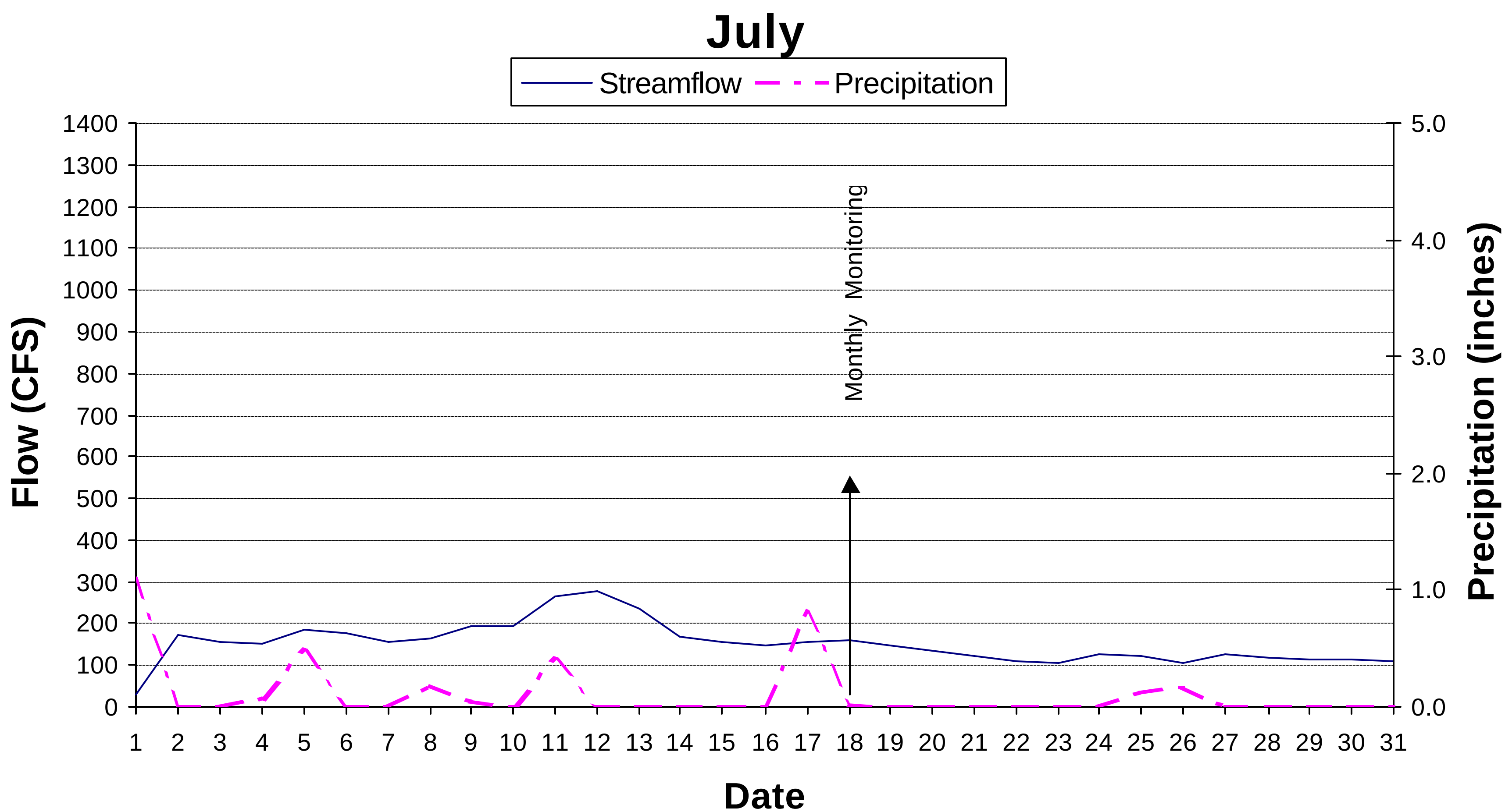

Figure 2-5. July streamflow and precipitation in the vicinity of F.E. Walter Reservoir in 2001

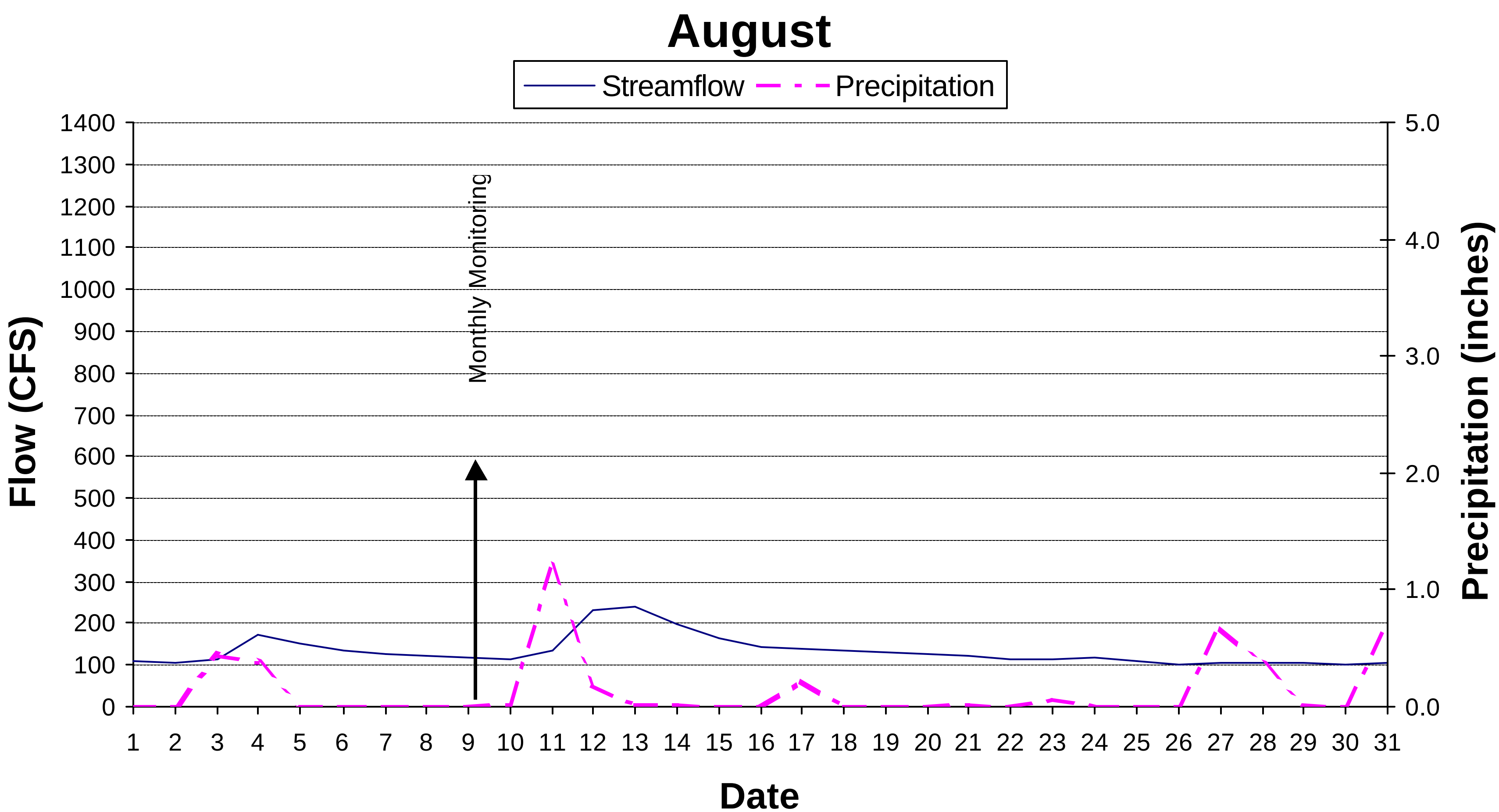

Figure 2-6. August streamflow and precipitation in the vicinity of F.E. Walter Reservoir during August 2001

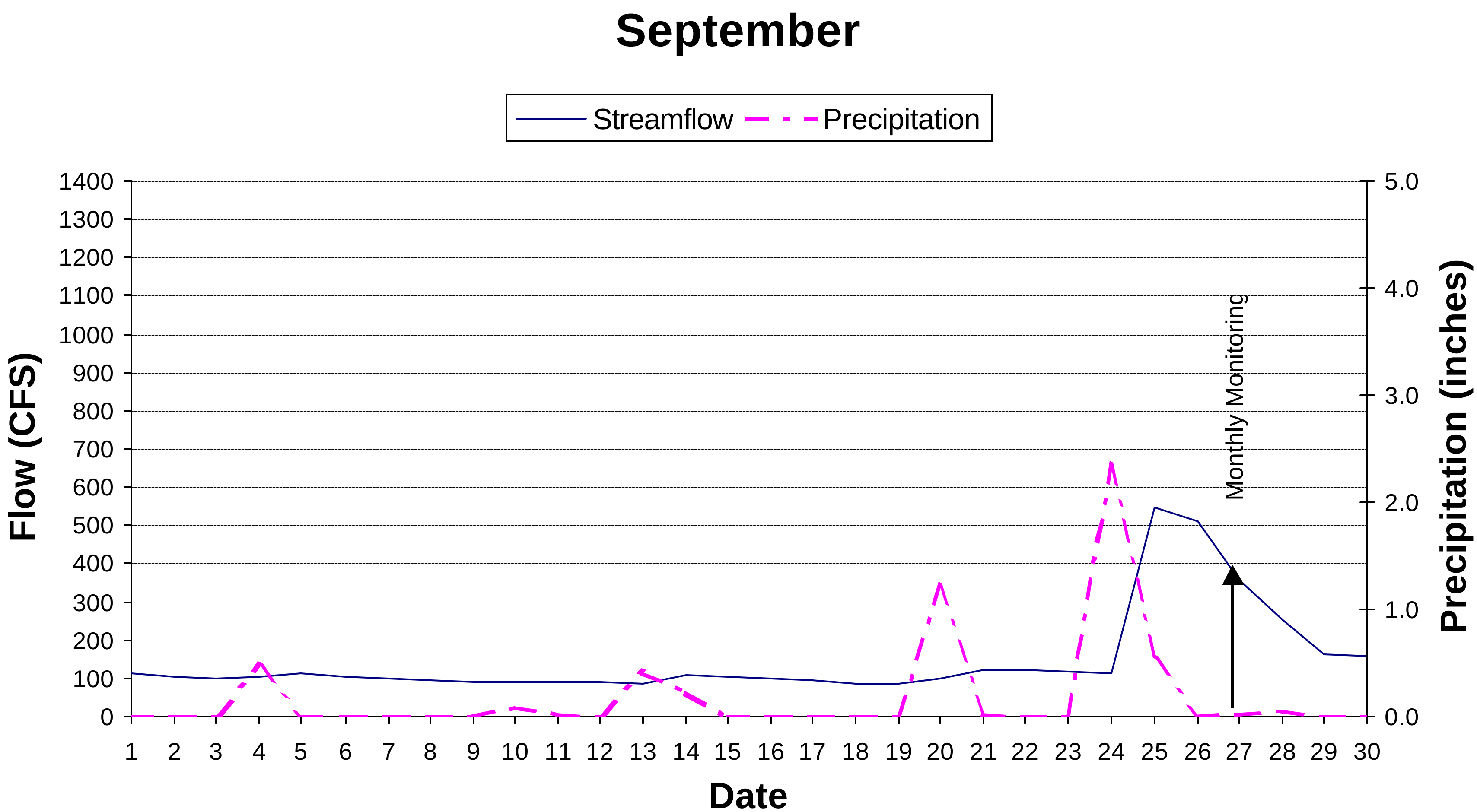

Figure 2-7. September streamflow and precipitation in the vicinity of F.E. Walter Reservoir during September 2001

Figure 2-8. October streamflow and precipitation in the vicinity of F.E. Walter Reservoir in 2001

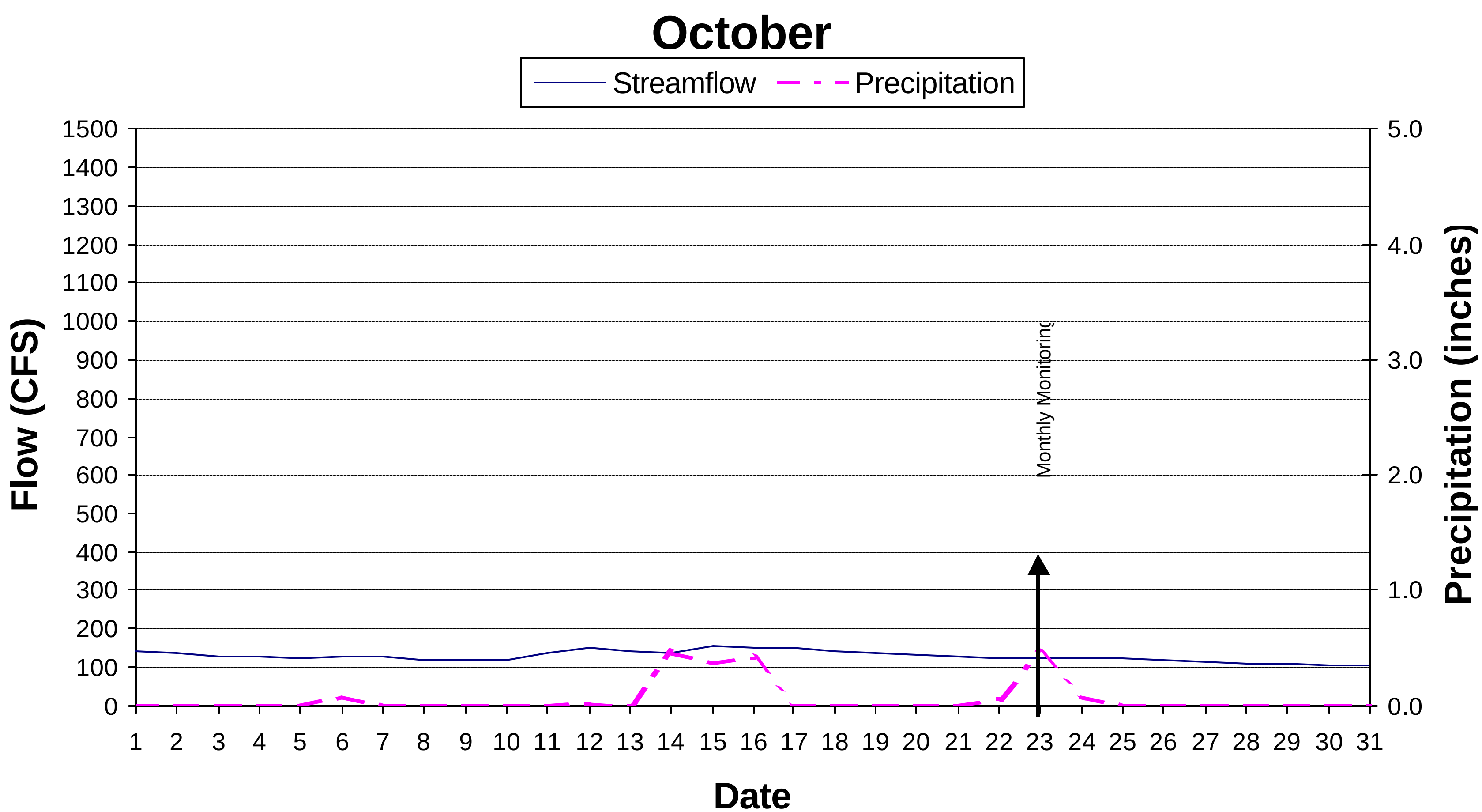

Table 2-4. Analytical methods, detection limits, and sample hold times for sediment priority pollutant metals and semivolatiles (SVOCs) monitored at F.E. Walter in 2001.

Parameter	EPA Method	Method Detection Limit (mg/kg)	Allowable Hold Time (days)	Max. Hold Time Achieved (days)
CONVENTIONALS				
Percent Solids	STM D2974	0.1		0
METALS				
Aluminum	6010B	80.2	180	12
Antimony	6010B	1.6	180	7
Arsenic	6010B	4	180	7
Barium	6010B	0.4	180	7
Beryllium	6010B	0.4	180	7
Cadmium	6010B	0.4	180	7
Calcium	6010B	1.6	180	7
Chromium	6010B	0.4	180	7
Cobalt	6010B	1.6	180	7
Copper	6010B	0.4	180	7
Iron	6010B	20	180	12
Lead	6010B	1.6	180	7
Magnesium	6010B	1.6	180	7
Manganese	6010B	0.4	180	7
Mercury	6010B	0.07	28	12
Nickel	6010B	0.4	180	7
Potassium	6010B	1.6	180	7
Selenium	6010B	3.0	180	7
Sodium	6010B	1.6	180	7
Vanadium	6010B	1.6	180	7
Zinc	6010B	0.4	180	7
SVOC (mg/kg)				
2,4,5-Trichlorophenol	8270C	397	40	7
2,4,6-Trichlorophenol	8270C	397	40	7
2,4-Dichlorophenol	8270C	397	40	7
2,4-Dimethylphenol	8270C	397	40	7
2,4-Dinitrophenol	8270C	397	40	7
2-Chlorophenol	8270C	397	40	7
2-Methylphenol	8270C	397	40	7
2-Nitrophenol	8270C	397	40	7
3-Methylphenol	8270C	397	40	7
4,6-Dinitro-2-methylphenol	8270C	397	40	7
4-Chloro-3-methylphenol	8270C	397	40	7
4-Methylphenol	8270C	397	40	7
4-Nitrophenol	8270C	397	40	7
Benzoic acid	8270C	397	40	7
Benzyl alcohol	8270C	397	40	7
Pentachlorophenol	8270C	397	40	7
Phenol	8270C	397	40	7

2.7 TREND ANALYSIS METHODS

Annual water quality, sediment contaminant, and drinking water monitoring have been conducted at F.E. Walter Reservoir since 1975. Data collected over these years were compiled in to an electronic database by the USACE (Versar 1996). The compilation of historical data enables the use of statistical trend analysis, an important tool in determining if the water quality at F.E. Walter Reservoir is changing. A number of different trend analysis methods are available, some more complicated than others. For the purpose of this report, we employed two general methods, regression analysis and the Mann-Kendall, or Seasonal Kendall, test.

2.7.1 Regression Analysis

The spatial and temporal distributions of the historical data were examined to determine which parameters had a sufficient time series to warrant meaningful trend analysis. Among the stations monitored for the major water quality parameters (e.g., nutrients, dissolved oxygen, total dissolved solids), downstream station WA-1 and reservoir station WA-2 were consistently sampled over the entire 23-year time series. Water quality trend analyses were limited to the spring (April through June) and summer (July through 15 October) periods. The "spring season" analyses were conceptualized as representing long-term trends associated with inputs to the reservoir during snow melt periods. The "summer season" analyses depicted conditions during periods of maximum productivity and greatest low DO stress. Trends at station WA-1 were analyzed separately to evaluate conditions in the Lehigh River downstream of the reservoir. Regression analyses were used to determine if significant change in parameter concentrations occurred over the past two decades. The slope of the regression line was used to estimate the yearly rate of change. For this report, regression analysis was applied to the water quality parameters: total nitrogen, total phosphorus, total dissolved solids, biochemical oxygen demand, and fecal coliform bacteria.

2.7.2 Mann-Kendall Analysis

In addition to regression analysis, the non-parametric Mann-Kendall test was used to determine trends for individual stations over the time span of historical monitoring at F.E. Walter Reservoir. The Mann-Kendall (or Seasonal Kendall) test scores all combinations of yearly change for the tested parameter with a +1 or –1 depending on whether parameter increased or decreased over the time interval. All of the scores are then summed and compared to the chi-square distribution to determine if the parameter has a significant trend (increasing or decreasing) over the time series. For this report, the Mann-Kendall test was applied to the water quality parameters: dissolved oxygen, ammonia, total nitrogen, total phosphorus, total dissolved solids, biochemical oxygen demand, and total and fecal coliform bacteria.

2.8 DRINKING WATER MONITORING

Drinking water was monitored in the operations building of F.E. Walter Reservoir (Table 2-1). Drinking water parameters were divided into two sets, A and B. Set A comprised bacteria parameters, total and fecal coliform (for analytical methods, see section 2.4), and nitrate and nitrite. Set A samples were collected 13 June and 9 August. Set B samples were analyzed for primary and secondary contaminants and were monitored 13 June. An extra coliform sampling was collected on 21 June. Table 2-5 summarizes the analytical methods, method detection limits, and sample hold times for each set B parameter. All of the drinking water quality parameters were analyzed within their respective maximum allowable hold times during 2001.

Table 2-5. Analytical methods, method detection limits, and sample hold times for drinking water monitored at F.E. Walter Reservoir in 2001

Parameter	Detection Limits	EPA Method	Allowable Hold Times (Days)	Maximum Hold Time Achieved (Days)
Aluminum	0.02	200.7	180	12
Antimony	0.05	200.8	180	12
Arsenic	0.05	200.7	180	12
Barium	0.005	200.7	180	12
Beryllium	0.005	200.7	183	12
Cadmium	0.005	200.7	180	12
Chromium	0.005	200.7	180	12
Copper	0.005	200.7	180	12
Iron	0.005	200.7	180	12
Lead	0.001	200.8	N/A	6
Magnesium	0.02	200.7	180	12
Manganese	0.005	200.7	180	12
Mercury	0.0002	245.1	28	12
Nickel	0.005	200.7	180	12
Selenium	1.0	200.8	183	26

Table 2-5. (Continued)

Parameter	Detection Limits	EPA Method	Allowable Hold Times (Days)	Maximum Hold Time Achieved (Days)
Silver	0.005	200.7	180	12
Sodium	0.02	200.7	180	12
Thallium	0.05	200.8	180	12
Zinc	0.005	200.7	180	12
Alkalinity as $CaCO_3$	2.0	SM 2320B	183	2
Chloride	1	300.0	28	12
Cyanide	0.007	SM 4500CN-C&E	14	12
Fluoride	0.1	SM 4500F-B	28	11
Hardness as $CaCO_3$	2.0	SM 3500-Ca-D	14	14
Foaming Agents	0.05	SM 5540C	2	1
Nitrate as N	1	SM4500	2	1
Nitrite as N	0.005	SM4500	2	1
Sulfate	5.0	300.0	28	7
Total Dissolved Solids	10.0	SM 2540C	7	5
pH	+/-0.01	150.1	N/A	1

N/A – Not applicable

3.0 RESULTS AND DISCUSSION

3.1 STRATIFICATION MONITORING

The following sections describe temporal and spatial patterns for the water quality parameters of temperature, dissolved oxygen (DO), percent saturation of DO, pH, and conductivity measured throughout the F.E. Walter Reservoir watershed during 2001. Additionally, patterns related to season and depths are described for station WA-2 located in the deepest portion of the reservoir. All of the data collected during the 2001 monitoring period are presented in Appendix Table A-1.

3.1.1 Temperature

Temperature of the surface waters of the F.E. Walter Reservoir watershed generally followed a similar pattern throughout the monitoring period. Temperatures increased throughout the summer and peaked in August at about 28 ºC, and decreased thereafter through October to 12 ºC (Fig. 3-1). Temperatures in surface waters of the reservoir-body (station WA-2, -6, and -7) were generally warmer than in tributaries (stations WA-3, WA-4, and WA-5) and downstream of the dam (WA-1) and throughout the monitoring period averaged 3 ºC higher.

The water column of F.E. Walter Reservoir was weakly stratified during 2001. Temperatures throughout the water column in all months were somewhat uniform, and the greatest difference between surface and bottom was about 7 ºC in June (Fig. 3-2). In April and October, the temperature of the water column was lowest and averaged about 12 ºC. In August, the temperature of the water column averaged 25 ºC and peaked at 28 ºC.

3.1.2 Dissolved Oxygen

Dissolved oxygen (DO) in the surface waters of F.E. Walter Reservoir followed a consistent pattern during 2001. Concentrations among all stations generally averaged 9-mg/L over the monitoring period and ranged from 6 to 11-mg/L (Fig. 3-3). Two exceptions were noted during the July monitoring; DO measured downstream of the reservoir (WA-1) and upstream of the reservoir on Tobyhanna Creek (WA-3) were elevated to supersaturated conditions. The DO concentration at WA-1 was 17.3-mg/L and the DO at WA-3 was 14.6-mg/L. High DO at these stations may be indicative of an algal bloom; however, chlorophyll concentrations measured at these stations were not elevated (see section 3.2.12).

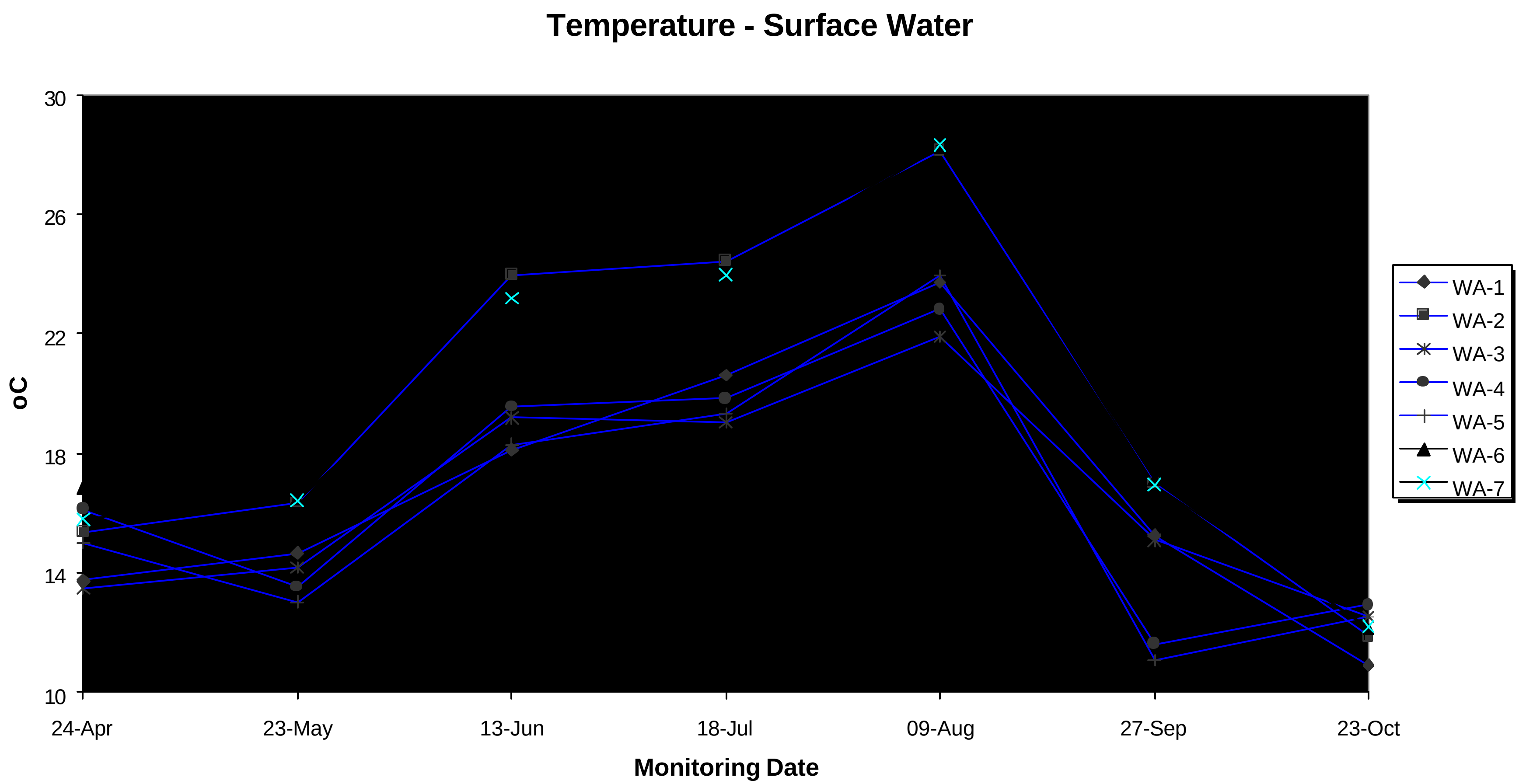

Figure 3-1. Temperature measured in surface waters of F.E. Walter Reservoir during 2001. See Appendix A for a summary of the plotted values.

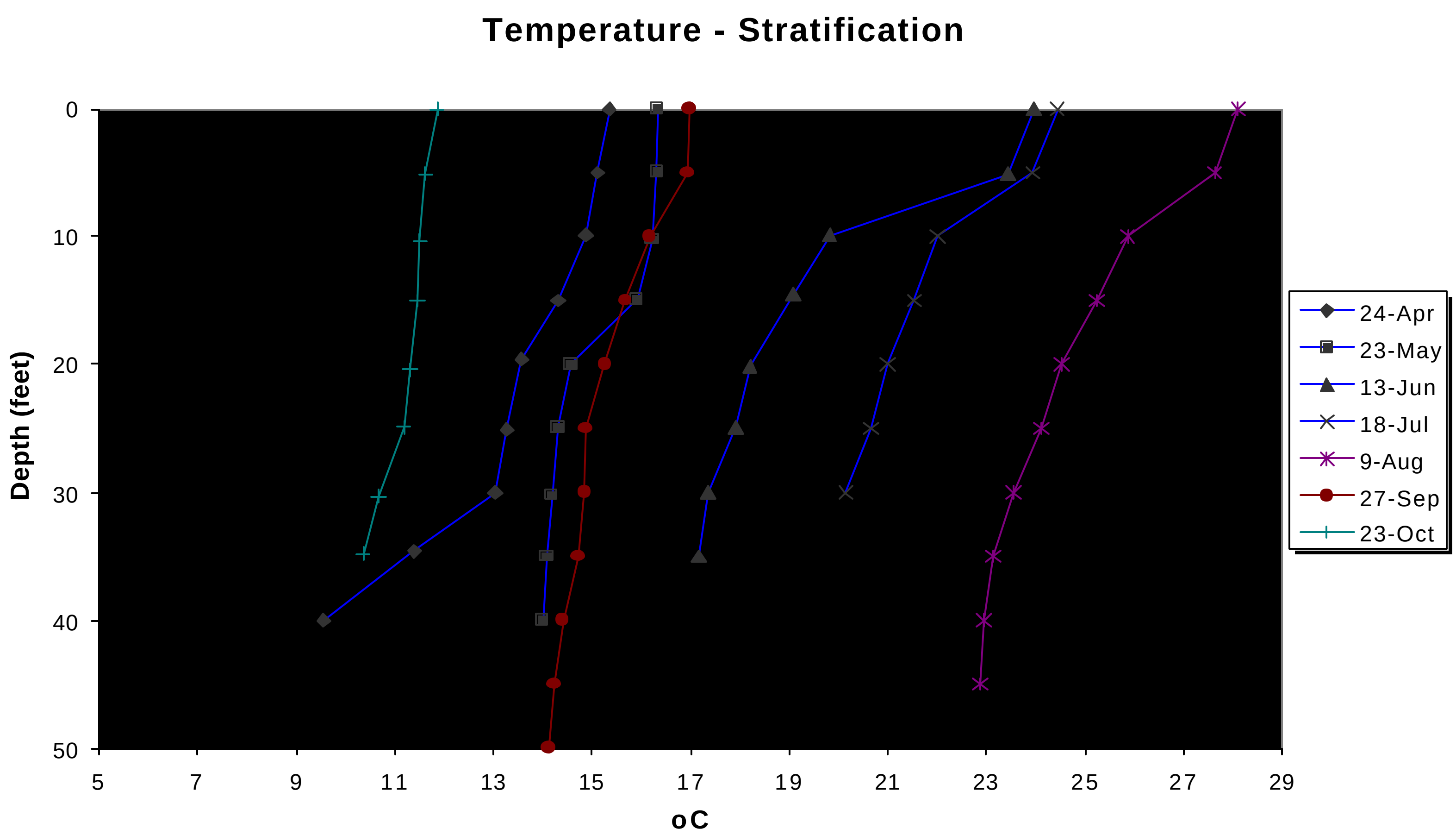

Figure 3-2. Stratification of temperature measured in the water column of F. E. Walter Reservoir at station WA-2 during 2001. See Appendix A for a summary of the plotted values

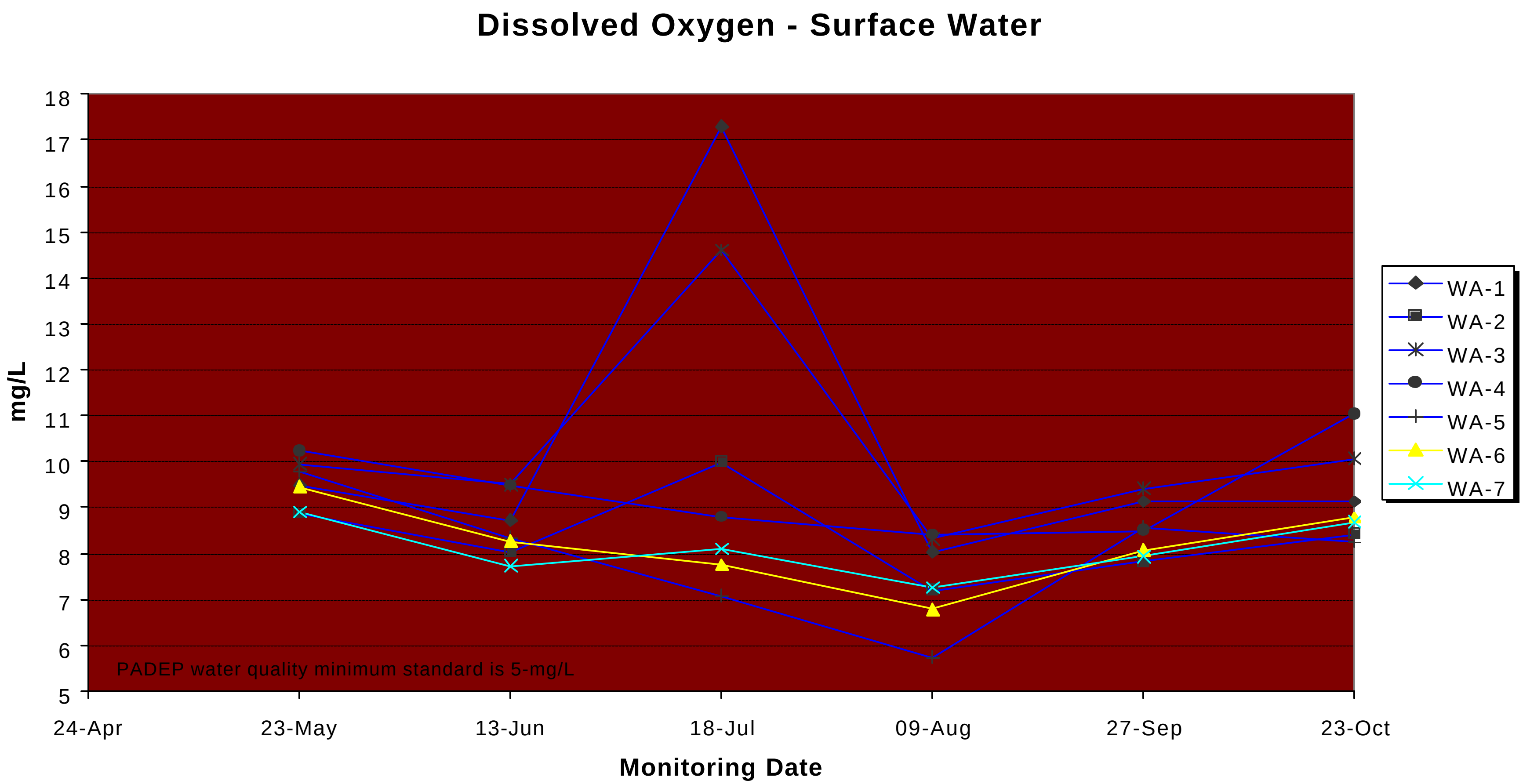

Figure 3-3. Percent saturation of dissolved oxygen measured in surface waters of F. E. Walter Reservoir during 2001. See Appendix A for a summary of the plotted values.

The water column of F.E. Walter Reservoir was weakly stratified with respect to DO during 2001. On most monitoring dates, the water column was relatively uniform with concentrations remaining stable throughout the water column (Fig. 3-4). In April, May, June, September, and October, concentrations were similar and averaged 7.9-mg/L throughout the water column. In July and August, the DO in the bottom 5 to 10 feet of the water column was low with concentrations ranging to 3.9-mg/L at the bottom.

With the exception of the bottom water in August at stations BZ-2 and BZ-7, F.E. Walter Reservoir was in compliance with the PADEP water quality standard for DO during 2001. The PADEP standard for DO is a minimum concentration of 5 mg/L. Throughout the remainder of the monitoring period, concentrations of DO in water column of the reservoir and its tributaries were greater than the minimum standard.

A seasonal trend analysis of DO was conducted for individual stations of F.E. Walter Reservoir, combining 2001 and historical data. The Mann-Kendall statistic was applied to station data collected over the past 22 years or more, separately for spring (April to June) and summer (July to September) seasons. Stations included in the analysis were representative of locations downstream (WA-1), main reservoir (WA-2), and upstream sources on Tobyhanna Creek (WA-3), Lehigh River (WA-4), and Bear Creek (WA-5). From the analysis, none of the spring or summer trends were significant (Table 3-1).

Table 3-1. Seasonal trends of dissolved oxygen concentration at individual stations of F.E. Walter Reservoir calculated with the Mann-Kendall Statistic.

Station	# of Years spring/summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate (mg/L)
Surface Water					
WA-1	26	NS	0.005	NS	-0.038
WA-2	27	NS	-0.036	NS	-0.051
WA-3	26	NS	-0.021	NS	-0.024
WA-4	27	NS	-0.022	NS	-0.028
WA-5	23	NS	-0.036	NS	-0.075

3.1.3 pH

Measures of pH in surface waters of F.E. Walter Reservoir generally followed a similar pattern during 2001. Among all stations, pH generally averaged about 7.1 throughout the monitoring period and ranged from 6.2 to 8.4 (Fig. 3-5).

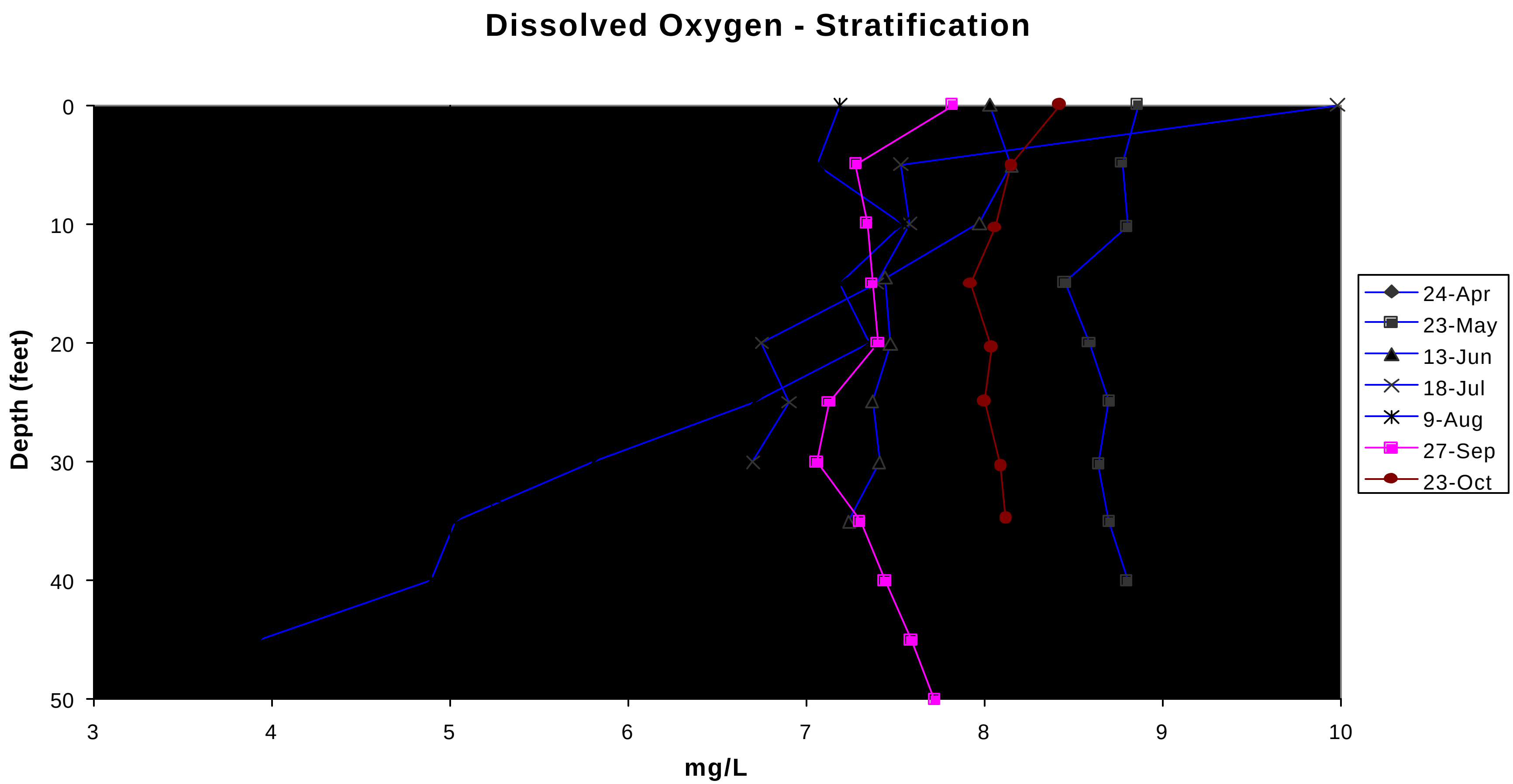

Figure 3-4. Dissolved oxygen measured in surface waters of F.E. Walter Reservoir during 2001. The PADEP water quality standard for DO is a minimum concentration of 5 mg/L. See Appendix A for a summary of the plotted values.

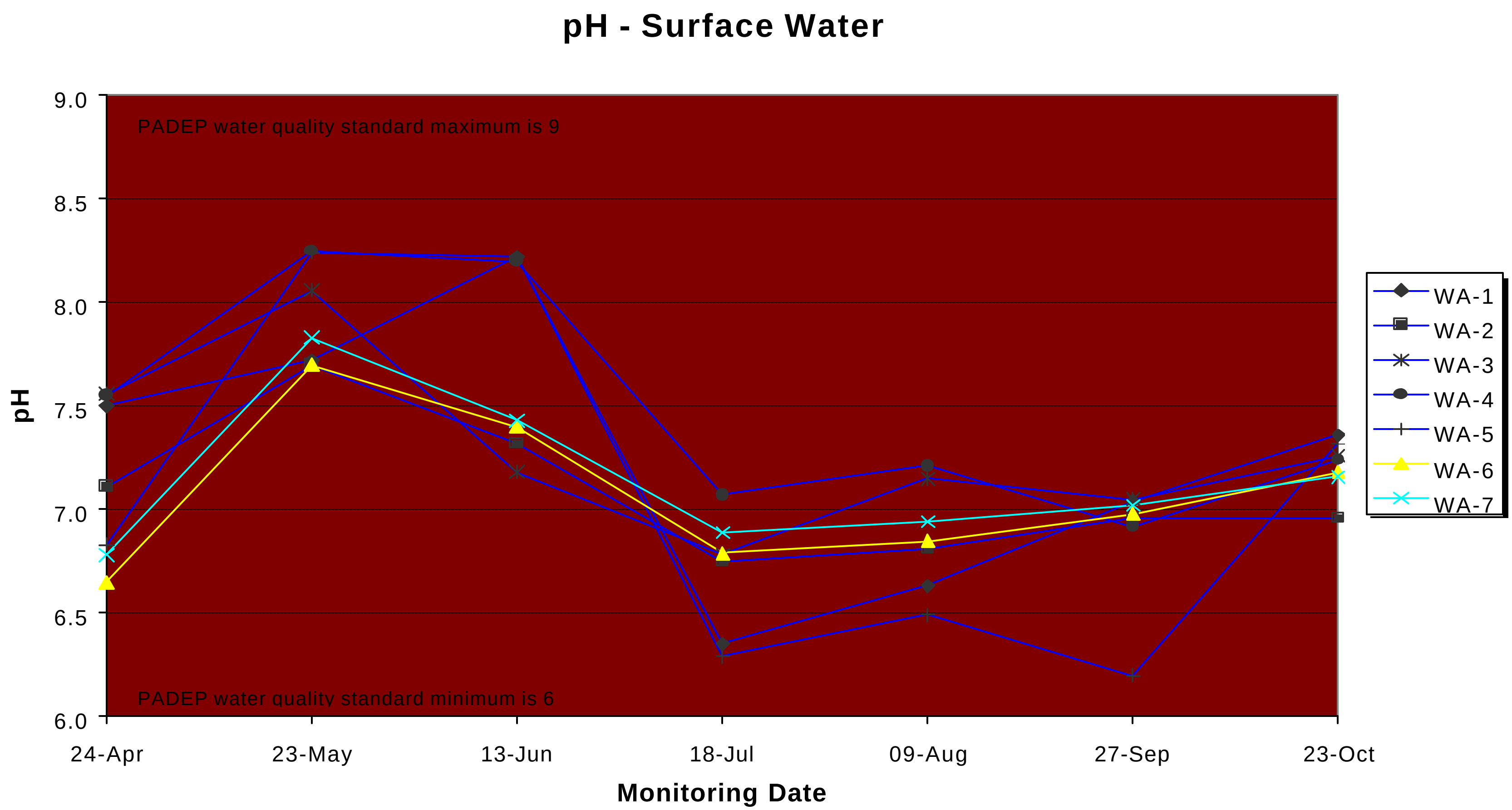

Figure 3-5. Measures of pH in surface waters of F.E. Walter Reservoir during 2001. The PADEP water quality standard for pH is an acceptable range from 6 to 9. See Appendix A for a summary of the plotted values.

The water column of F.E. Walter Reservoir was weakly stratified with respect to pH during 2001. On most monitoring dates, measures of pH were relatively uniform throughout the water column (Fig. 3-6). In May, pH was highest and averaged about 7.9. In July, pH was lowest averaging 6.5 and ranged from 6.2 to 6.8.

During 2001, all measures of pH in the water column of F.E. Walter Reservoir were in compliance with PADEP water quality standards. The water quality standard for pH is a range of acceptable measures between 6 and 9. Throughout the monitoring period, measures of pH at all stations and depths were within the limits of the water quality standard.

3.1.4 Conductivity

For the most part, conductivity among the surface waters of F.E. Walter Reservoir followed a consistent pattern during 2001. Conductivity at most stations averaged about 0.083-mS/cm throughout the monitoring period and ranged from 0.07 to 0.14-mS/cm (Fig. 3-7). Conductivity was typically higher upstream of the reservoir at stations WA-3 and WA-5. At these locations, conductivity averaged 0.097-mS/cm.

Conductivity in the water column of F.E. Walter Reservoir was weakly stratified during 2001. In most months, measures were generally uniform throughout, but followed a slight increasing trend as the season progressed (Fig. 3-8). In July, conductivity was lowest at approximately 0.068-mS/cm. Thereafter, through September, conductivity increased on each monitoring date to an average of 0.09-mS/cm. In early August, conductivity demonstrated the strongest stratification pattern with measures ranging from 0.08-mS/cm at the surface to 0.09-mS/cm in the lower water column.

3.2 WATER COLUMN CHEMISTRY MONITORING

The following sections describe temporal, spatial, and depth related patterns for water quality measured in the water column of F.E. Walter Reservoir during 2001 (Table 3–2). Where appropriate, trends in surface water quality are discussed based on the regression and Mann-Kendall analysis of 2001 data and the F.E. Walter Reservoir water quality database.

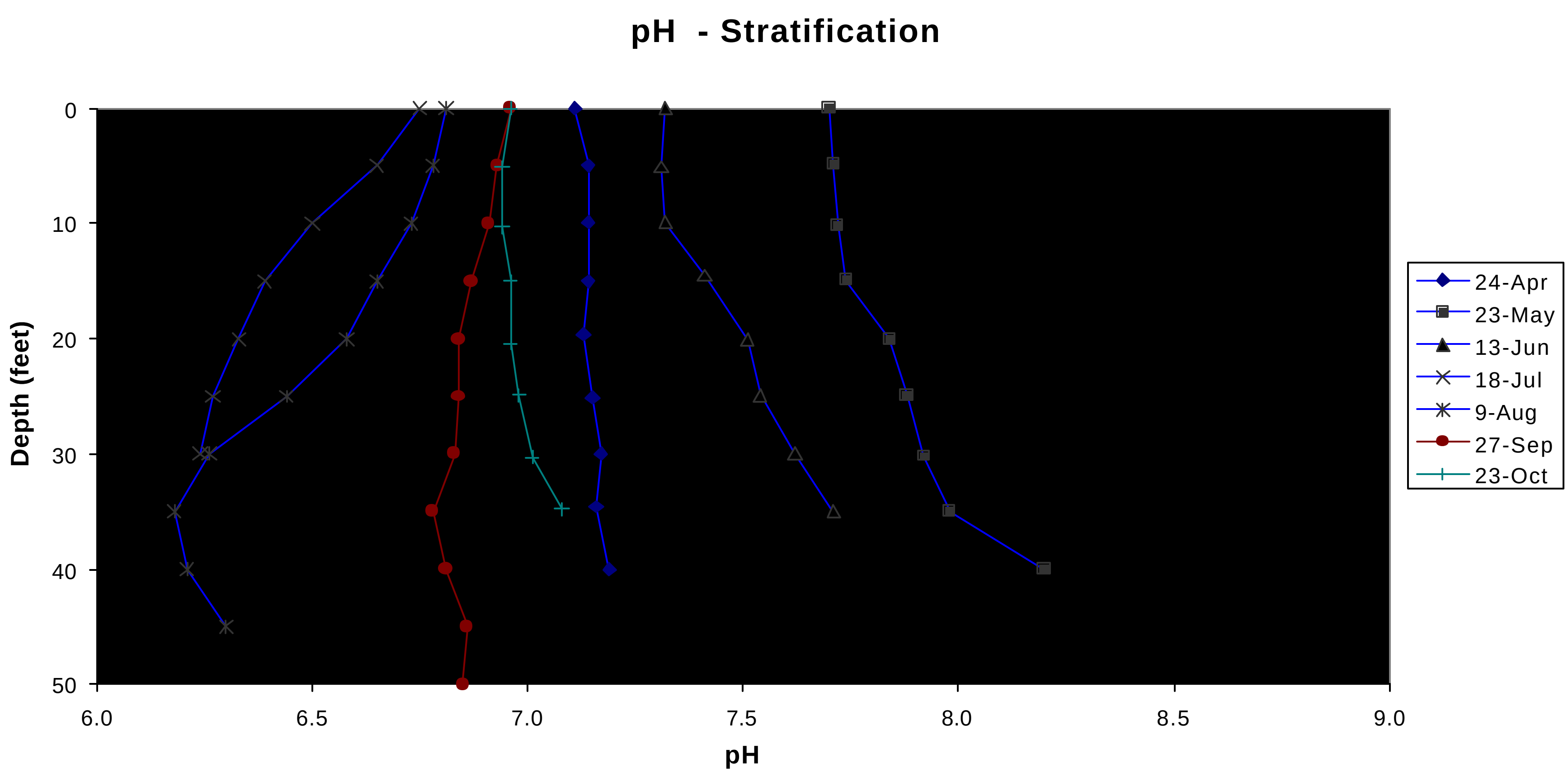

Figure 3-6. Stratification of pH measured in the water column of F.E. Walter Reservoir at station WA-2 during 2001. The PADEP water quality standard pH is an acceptable range from 6 to 9. See Appendix A for a summary of the plotted values.

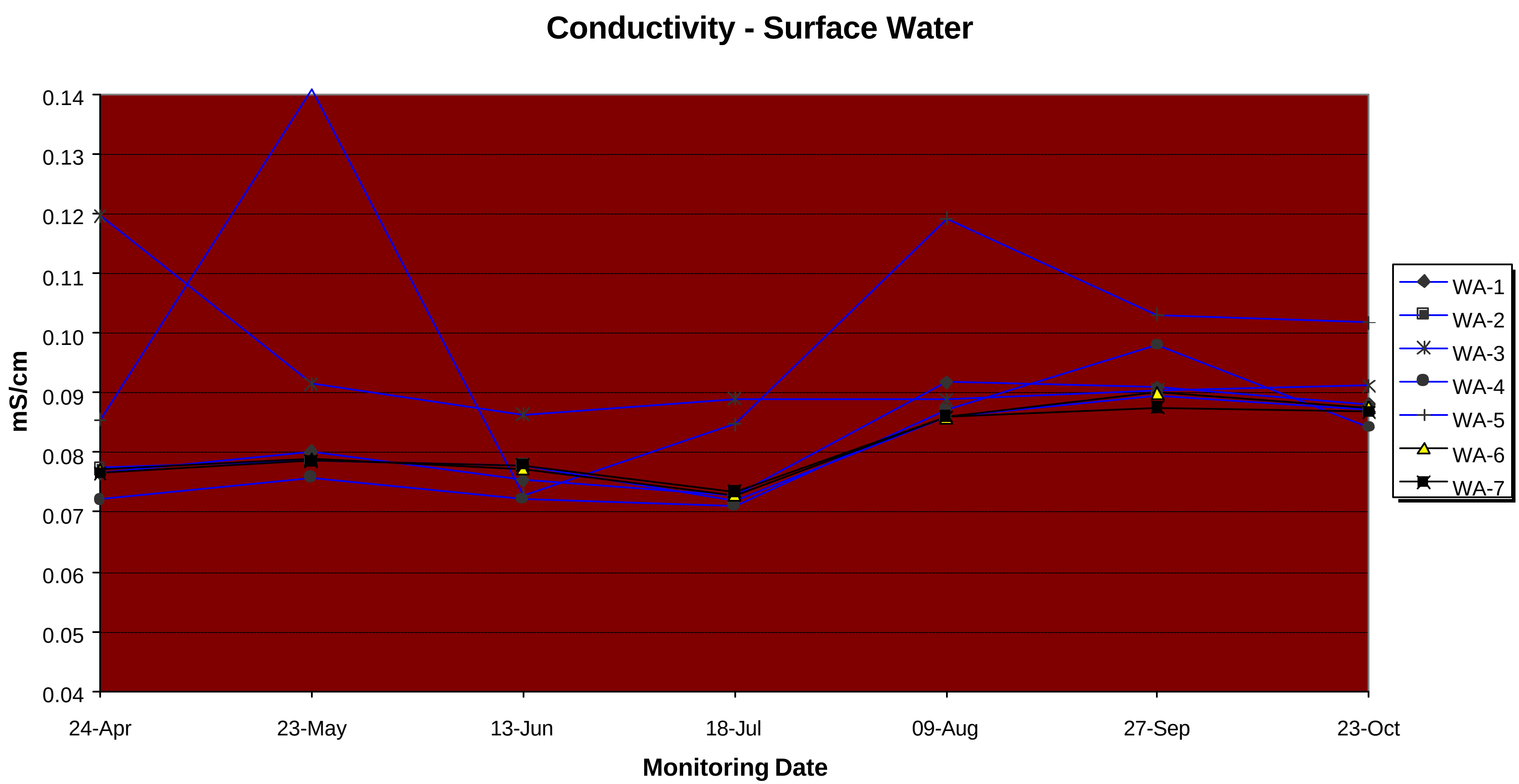

Figure 3-7. Conductivity measured in surface waters of F.E. Walter Reservoir during 2001. See Appendix A for a summary of the plotted values.

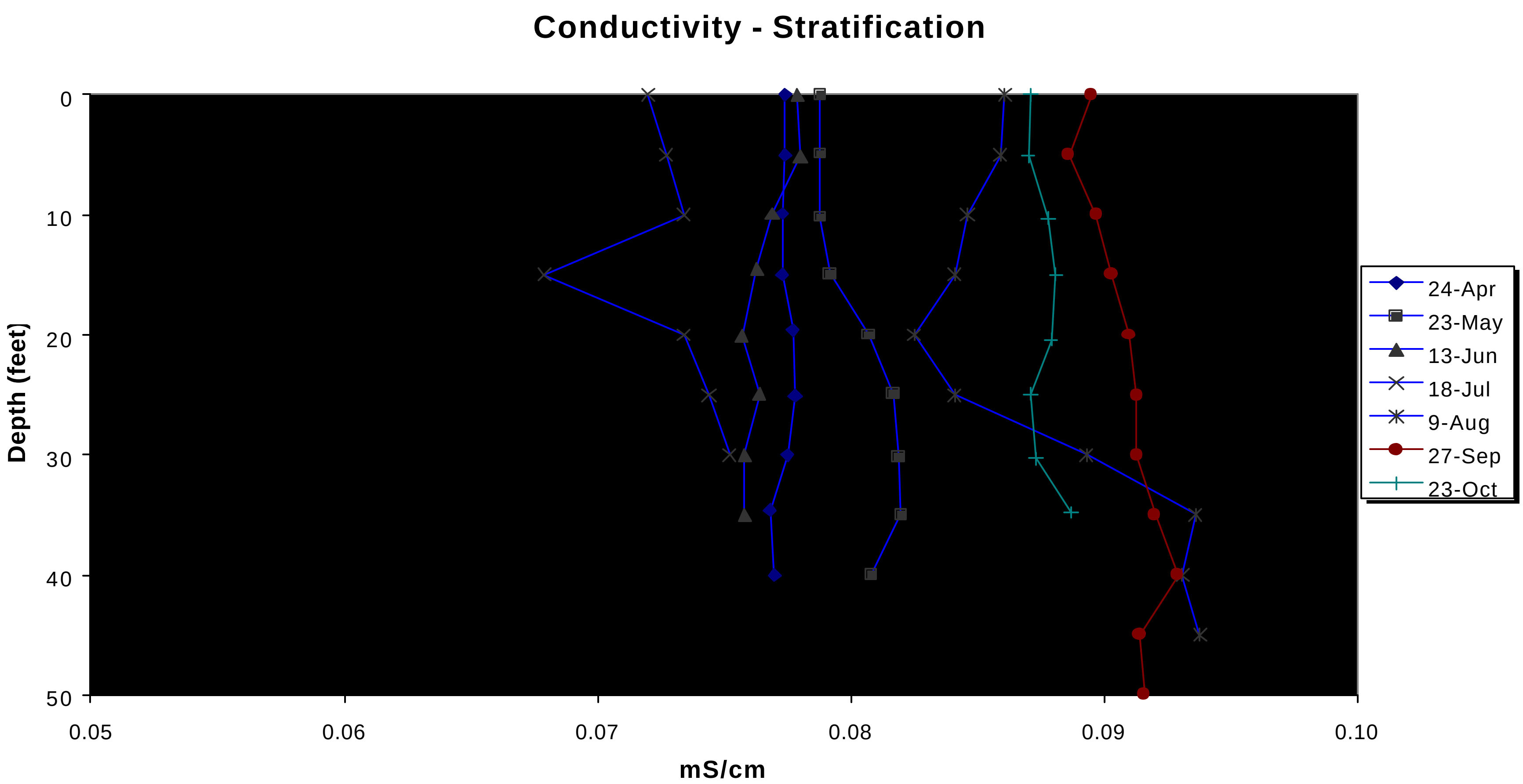

Figure 3-8. Stratification of conductivity measured in the water column of F. E. Walter Reservoir at station WA-2 during 2001. See Appendix A for a summary of the plotted values.

Table 3-2. Summary of surface, middle, and bottom water quality monitoring data for F.E. Walter Reservoir in 2001

STATION	DATE	NH3	NO2	NO3	PO4	TKN	TP	TDS	TSS	BOD5	ALK	CHL_A
WA-1S	24-Apr	< 0.10	< 0.005	0.10	< 0.05	0.20	< 0.05	50.0	7.0	< 3.0	4.0	2.0
	23-May	< 0.10	< 0.005	0.30	0.06	0.40	< 0.05	30.0	< 1.0	< 3.0	6.0	1.9
	13-Jun	0.20	< 0.005	< 0.10	0.07	3.10	< 0.05	88.0	13.0	< 1.0	4.0	1.2
	18-Jul	< 0.10	< 0.005	0.20	< 0.05	0.20	< 0.05	78.0	13.0	< 2.0	8.0	2.4
	09-Aug	0.14	< 0.100	0.10	0.06	0.30	< 0.05	62.0	12.0	< 2.0	10.0	1.1
	27-Sep	0.90	< 0.100	< 0.10	< 0.05	< 0.20	< 0.05	68.0	2.0	< 2.0	6.0	7.1
	23-Oct	0.30	< 0.500	< 0.50	0.08	< 1.00	< 0.05	82.0	< 1.0	< 2.0	12.0	2.9
Mean		0.26	0.103	0.20	0.06	0.77	0.05	65.4	7.0	2.1	7.1	2.7
Maximum		0.90	0.500	0.50	0.08	3.10	0.05	88.0	13.0	3.0	12.0	7.1
Minimum		0.10	0.005	0.10	0.05	0.20	0.05	30.0	1.0	1.0	4.0	1.1
Std. Dev		0.29	0.181	0.15	0.01	1.07	0.00	20.2	5.7	0.7	3.0	2.1
No. of D		4	0	4	4	5	0	7	5	0	7	7
WA-2S	24-Apr	< 0.10	< 0.005	< 0.10	0.07	0.10	< 0.05	32.0	2.0	< 3.0	4.0	1.6
	23-May	< 0.10	< 0.005	0.30	0.05	0.30	< 0.05	24.0	6.0	< 3.0	6.0	6.1
	13-Jun	0.10	< 0.005	< 0.10	0.38	3.90	< 0.05	76.0	7.0	< 1.0	6.0	4.0
	18-Jul	< 0.10	< 0.005	0.20	< 0.05	0.20	< 0.05	66.0	3.0	< 2.0	4.0	2.8
	09-Aug	< 0.10	< 0.100	0.10	0.05	0.10	< 0.05	26.0	10.0	< 2.0	10.0	1.7
	27-Sep	0.10	< 0.100	0.10	0.05	< 0.20	< 0.05	70.0	2.0	< 2.0	6.0	5.9
	23-Oct	0.30	< 0.500	< 0.50	0.07	< 1.00	< 0.05	52.0	< 1.0	< 2.0	12.0	4.0
Mean		0.13	0.103	0.20	0.10	0.83	0.05	49.4	4.4	2.1	6.9	3.7
Maximum		0.30	0.500	0.50	0.38	3.90	0.05	76.0	10.0	3.0	12.0	6.1
Minimum		0.10	0.005	0.10	0.05	0.10	0.05	24.0	1.0	1.0	4.0	1.6
Std. Dev		0.08	0.181	0.15	0.12	1.39	0.00	22.0	3.3	0.7	3.0	1.8
No. of D		3	0	4	6	5	0	7	6	0	7	7
WA-2M	24-Apr	< 0.10	< 0.005	0.10	< 0.05	0.20	< 0.05	38.0	2.0	< 3.0	3.0	2.1
	23-May	< 0.10	< 0.005	0.40	0.05	0.40	< 0.05	10.0	10.0	< 3.0	8.0	1.4
	13-Jun	0.10	< 0.005	< 0.10	0.07	2.00	< 0.05	66.0	6.0	< 1.0	12.0	2.6
	18-Jul	< 0.10	< 0.005	0.20	< 0.05	0.30	< 0.05	76.0	7.0	< 2.0	5.0	7.2
	09-Aug	< 0.10	< 0.100	0.10	0.05	0.15	< 0.05	26.0	6.0	< 2.0	11.0	3.2
	27-Sep	< 0.10	< 0.100	< 0.10	0.07	< 0.20	< 0.05	64.0	3.0	< 2.0	6.0	7.4
	23-Oct	0.30	< 0.500	< 0.50	0.06	2.90	< 0.05	164.0	< 1.0	< 2.0	10.0	3.8
Mean		0.13	0.103	0.21	0.06	0.88	0.05	63.4	5.0	2.1	7.9	3.9
Maximum		0.30	0.500	0.50	0.07	2.90	0.05	164.0	10.0	3.0	12.0	7.4
Minimum		0.10	0.005	0.10	0.05	0.15	0.05	10.0	1.0	1.0	3.0	1.4
Std. Dev		0.08	0.181	0.17	0.01	1.11	0.00	50.3	3.2	0.7	3.3	2.4
No. of D		2	0	4	5	6	0	7	6	0	7	7

Table 3-2. (Continued)

STATION	DATE	NH3	NO2	NO3	PO4	TKN	TP	TDS	TSS	BOD5	ALK	CHL_A
WA-2B	24-Apr	< 0.10	< 0.005	< 0.10	< 0.05	0.10	< 0.05	26.0	14.0	< 3.0	3.0	0.8
	23-May	< 0.10	< 0.005	0.40	< 0.05	0.30	< 0.05	18.0	8.0	< 3.0	8.0	1.0
	13-Jun	< 0.10	< 0.005	< 0.10	< 0.05	1.40	< 0.05	74.0	12.0	< 1.0	5.0	1.1
	18-Jul	< 0.10	< 0.005	0.10	0.07	0.20	< 0.05	52.0	6.0	< 2.0	6.0	0.7
	09-Aug	0.29	< 0.100	0.10	0.05	0.31	< 0.05	28.0	1.0	< 2.0	10.0	1.0
	27-Sep	< 0.10	< 0.100	< 0.10	0.05	< 0.20	< 0.05	70.0	< 1.0	< 2.0	8.0	7.1
	23-Oct	0.20	< 0.500	< 0.50	0.06	< 1.00	< 0.05	146.0	5.0	< 2.0	10.0	1.8
Mean		0.14	0.103	0.20	0.05	0.50	0.05	59.1	6.7	2.1	7.1	1.9
Maximum		0.29	0.500	0.50	0.07	1.40	0.05	146.0	14.0	3.0	10.0	7.1
Minimum		0.10	0.005	0.10	0.05	0.10	0.05	18.0	1.0	1.0	3.0	0.7
Std. Dev		0.08	0.181	0.17	0.01	0.50	0.00	44.1	5.0	0.7	2.6	2.3
No. of D		2	0	3	4	5	0	7	6	0	7	7
WA-3S	24-Apr	< 0.10	< 0.005	0.10	< 0.05	0.20	< 0.05	44.0	8.0	< 3.0	3.0	2.6
	23-May	< 0.10	< 0.005	0.40	0.06	0.50	< 0.05	46.0	10.0	< 3.0	8.0	1.6
	13-Jun	< 0.10	< 0.005	< 0.10	0.05	1.80	< 0.05	98.0	8.0	< 1.0	7.0	1.8
	18-Jul	< 0.10	< 0.005	0.20	0.06	0.50	< 0.05	58.0	18.0	< 2.0	9.0	1.5
	09-Aug	0.12	< 0.100	0.10	< 0.05	0.21	< 0.05	40.0	8.0	< 2.0	10.0	1.2
	27-Sep	< 0.10	< 0.100	< 0.10	< 0.05	< 0.20	< 0.05	64.0	3.0	< 2.0	8.0	15.3
	23-Oct	0.20	< 0.500	< 0.50	0.07	< 1.00	< 0.05	48.0	< 1.0	< 2.0	12.0	5.0
Mean		0.12	0.103	0.21	0.06	0.63	0.05	56.9	8.0	2.1	8.1	4.1
Maximum		0.20	0.500	0.50	0.07	1.80	0.05	98.0	18.0	3.0	12.0	15.3
Minimum		0.10	0.005	0.10	0.05	0.20	0.05	40.0	1.0	1.0	3.0	1.2
Std. Dev		0.04	0.181	0.17	0.01	0.59	0.00	20.0	5.4	0.7	2.8	5.1
No. of D		2	0	4	4	5	0	7	6	0	7	7
WA-4S	24-Apr	< 0.10	< 0.005	0.10	< 0.05	0.30	< 0.05	28.0	10.0	< 3.0	5.0	2.0
	23-May	< 0.10	< 0.005	0.40	0.05	0.30	< 0.05	28.0	3.0	< 3.0	6.0	1.1
	13-Jun	< 0.10	< 0.005	< 0.10	0.06	3.90	< 0.05	84.0	13.0	< 1.0	7.0	1.0
	18-Jul	0.20	< 0.005	0.10	< 0.05	0.40	< 0.05	58.0	8.0	< 2.0	7.0	0.9
	09-Aug	0.11	< 0.100	0.10	< 0.05	0.18	< 0.05	34.0	1.0	< 2.0	18.0	1.4
	27-Sep	< 0.10	< 0.100	< 0.10	0.06	0.20	< 0.05	54.0	2.0	< 2.0	10.0	1.5
	23-Oct	0.10	< 0.500	< 0.50	0.07	< 1.00	< 0.05	72.0	< 1.0	< 2.0	14.0	0.8
Mean		0.12	0.103	0.20	0.06	0.90	0.05	51.1	5.4	2.1	9.6	1.3
Maximum		0.20	0.500	0.50	0.07	3.90	0.05	84.0	13.0	3.0	18.0	2.0
Minimum		0.10	0.005	0.10	0.05	0.18	0.05	28.0	1.0	1.0	5.0	0.8
Std. Dev		0.04	0.181	0.17	0.01	1.35	0.00	22.1	4.9	0.7	4.8	0.4
No. of D		3	0	4	4	6	0	7	6	0	7	7

STATION	DATE	NH3	NO2	NO3	PO4	TKN	TP	TDS	TSS	BOD5	ALK	CHL_A
Table 3-2. (Continued)												
WA-5S	24-Apr	< 0.10	< 0.005	< 0.10	< 0.05	0.20	< 0.05	42.0	3.0	< 3.0	< 1.0	2.0
	23-May	< 0.10	< 0.005	1.10	0.05	0.50	< 0.05	50.0	6.0	< 3.0	4.0	0.7
	13-Jun	< 0.10	< 0.005	< 0.10	< 0.05	2.30	< 0.05	76.0	13.0	< 1.0	2.0	0.8
	18-Jul	0.20	< 0.005	0.10	< 0.05	0.50	< 0.05	56.0	6.0	< 2.0	< 1.0	1.0
	09-Aug	0.12	< 0.100	< 0.10	< 0.05	0.18	< 0.05	34.0	4.0	< 2.0	5.0	1.8
	27-Sep	< 0.10	< 0.100	< 0.10	0.06	0.30	< 0.05	72.0	38.0	< 2.0	4.0	2.0
	23-Oct	< 0.10	< 0.500	< 0.50	0.06	< 1.00	< 0.05	38.0	< 1.0	< 2.0	6.0	0.3
Mean		0.12	0.103	0.30	0.05	0.71	0.05	52.6	10.1	2.1	3.3	1.2
Maximum		0.20	0.500	1.10	0.06	2.30	0.05	76.0	38.0	3.0	6.0	2.0
Minimum		0.10	0.005	0.10	0.05	0.18	0.05	34.0	1.0	1.0	1.0	0.3
Std. Dev		0.04	0.181	0.38	0.00	0.75	0.00	16.4	12.9	0.7	2.0	0.7
No. of D		2	0	2	3	6	0	7	6	0	5	7
WA-6S	24-Apr	< 0.10	< 0.005	< 0.10	< 0.05	0.10	< 0.05	20.0	1.0	< 3.0	3.0	0.9
	23-May	< 0.10	< 0.005	0.40	0.06	0.70	< 0.05	18.0	2.0	< 3.0	6.0	6.4
	13-Jun	< 0.10	< 0.005	< 0.10	0.07	1.90	< 0.05	96.0	3.0	< 1.0	5.0	3.2
	18-Jul	0.20	< 0.005	0.10	< 0.05	0.40	< 0.05	42.0	1.0	< 2.0	6.0	3.7
	09-Aug	0.10	< 0.100	0.10	0.05	0.23	< 0.05	30.0	8.0	< 2.0	10.0	1.2
	27-Sep	< 0.10	< 0.100	< 0.10	0.06	0.20	< 0.05	62.0	1.0	< 2.0	8.0	7.5
	23-Oct	0.20	< 0.500	< 0.50	0.11	< 1.00	< 0.05	56.0	< 1.0	< 2.0	10.0	5.1
Mean		0.13	0.103	0.20	0.06	0.65	0.05	46.3	2.4	2.1	6.9	4.0
Maximum		0.20	0.500	0.50	0.11	1.90	0.05	96.0	8.0	3.0	10.0	7.5
Minimum		0.10	0.005	0.10	0.05	0.10	0.05	18.0	1.0	1.0	3.0	0.9
Std. Dev		0.05	0.181	0.17	0.02	0.64	0.00	27.7	2.6	0.7	2.6	2.5
No. of D		3	0	3	5	6	0	7	6	0	7	7
WA-6M	24-Apr	< 0.10	< 0.005	< 0.10	< 0.05	0.10	< 0.05	22.0	8.0	< 3.0	2.0	0.9
	23-May	< 0.10	< 0.005	0.40	< 0.05	< 0.10	< 0.05	34.0	1.0	< 3.0	6.0	2.3
	13-Jun	< 0.10	< 0.005	< 0.10	< 0.05	2.00	< 0.05	68.0	9.0	< 1.0	4.0	2.6
	18-Jul	0.10	< 0.005	0.50	< 0.05	0.60	< 0.05	48.0	9.0	< 2.0	6.0	11.8
	09-Aug	< 0.10	< 0.100	0.10	0.05	0.11	< 0.05	28.0	< 1.0	< 2.0	8.0	3.8
	27-Sep	< 0.10	< 0.100	< 0.10	0.06	< 0.20	< 0.05	66.0	2.0	< 2.0	8.0	3.7
	23-Oct	0.10	< 0.500	< 0.50	< 0.05	< 1.00	< 0.05	76.0	< 1.0	< 2.0	10.0	6.6
Mean		0.10	0.103	0.26	0.05	0.59	0.05	48.9	4.4	2.1	6.3	4.5
Maximum		0.10	0.500	0.50	0.06	2.00	0.05	76.0	9.0	3.0	10.0	11.8
Minimum		0.10	0.005	0.10	0.05	0.10	0.05	22.0	1.0	1.0	2.0	0.9
Std. Dev		0.00	0.181	0.20	0.00	0.71	0.00	21.5	4.0	0.7	2.7	3.7
No. of D		2	0	3	2	4	0	7	5	0	7	7

Table 3-2. (Continued)

STATION	DATE	NH3	NO2	NO3	PO4	TKN	TP	TDS	TSS	BOD5	ALK	CHL_A
WA-6B	24-Apr	< 0.10	< 0.005	0.10	< 0.05	0.20	< 0.05	18.0	3.0	< 3.0	2.0	1.4
	23-May	< 0.10	< 0.005	0.40	< 0.05	< 0.10	< 0.05	30.0	5.0	< 3.0	8.0	1.1
	13-Jun	0.20	< 0.005	< 0.10	< 0.05	1.50	< 0.05	56.0	11.0	< 1.0	5.0	1.1
	18-Jul	< 0.10	< 0.005	0.30	< 0.05	0.40	< 0.05	48.0	1.0	< 2.0	6.4	6.8
	09-Aug	< 0.10	< 0.100	0.10	0.05	0.14	< 0.05	20.0	1.0	< 2.0	8.0	6.8
	27-Sep	< 0.10	< 0.100	< 0.10	0.06	< 0.20	< 0.05	62.0	< 1.0	< 2.0	6.0	4.2
	23-Oct	0.10	< 0.500	< 0.50	< 0.05	< 1.00	< 0.05	60.0	1.0	< 2.0	10.0	4.8
Mean		0.11	0.103	0.23	0.05	0.51	0.05	42.0	3.3	2.1	6.5	3.7
Maximum		0.20	0.500	0.50	0.06	1.50	0.05	62.0	11.0	3.0	10.0	6.8
Minimum		0.10	0.005	0.10	0.05	0.10	0.05	18.0	1.0	1.0	2.0	1.1
Std. Dev		0.04	0.181	0.17	0.00	0.54	0.00	19.0	3.7	0.7	2.6	2.5
No. of D		2	0	4	2	4	0	7	6	0	7	7
WA-7S	24-Apr	< 0.10	< 0.005	< 0.10	< 0.05	0.20	< 0.05	< 10.0	1.0	< 3.0	5.0	2.0
	23-May	< 0.10	< 0.005	0.40	0.06	< 0.10	< 0.05	< 10.0	8.0	< 3.0	8.0	7.0
	13-Jun	< 0.10	< 0.005	< 0.10	0.07	1.20	< 0.05	100.0	9.0	< 1.0	5.0	5.6
	18-Jul	0.10	< 0.005	0.30	< 0.05	1.00	< 0.05	42.0	2.0	< 2.0	6.0	3.0
	09-Aug	< 0.10	< 0.100	0.10	0.06	< 0.10	< 0.05	18.0	< 1.0	< 2.0	10.0	2.5
	27-Sep	< 0.10	< 0.100	< 0.10	0.07	< 0.20	< 0.05	72.0	14.0	< 2.0	6.0	6.8
	23-Oct	0.20	< 0.500	< 0.50	< 0.05	< 1.00	< 0.05	54.0	5.0	< 2.0	14.0	6.8
Mean		0.11	0.103	0.23	0.06	0.54	0.05	43.7	5.7	2.1	7.7	4.8
Maximum		0.20	0.500	0.50	0.07	1.20	0.05	100.0	14.0	3.0	14.0	7.0
Minimum		0.10	0.005	0.10	0.05	0.10	0.05	10.0	1.0	1.0	5.0	2.0
Std. Dev		0.04	0.181	0.17	0.01	0.50	0.00	34.2	4.9	0.7	3.3	2.2
No. of D		2	0	3	4	3	0	5	6	0	7	7
WA-7M	24-Apr	< 0.10	< 0.005	< 0.10	< 0.05	0.10	< 0.05	20.0	9.0	< 3.0	2.0	2.3
	23-May	< 0.10	< 0.005	0.30	0.07	0.10	< 0.05	20.0	8.0	< 3.0	8.0	3.5
	13-Jun	< 0.10	< 0.005	< 0.10	< 0.05	2.10	< 0.05	68.0	11.0	< 1.0	6.0	1.4
	18-Jul	0.10	< 0.005	0.40	< 0.05	1.00	< 0.05	50.0	3.0	< 2.0	5.0	1.3
	09-Aug	< 0.10	< 0.100	0.10	0.05	0.12	< 0.05	42.0	9.0	< 2.0	12.0	1.4
	27-Sep	< 0.10	< 0.100	< 0.10	0.05	< 0.20	< 0.05	52.0	1.0	< 2.0	8.0	5.6
	23-Oct	< 0.10	< 0.500	< 0.50	0.06	< 1.00	< 0.05	56.0	1.0	< 2.0	12.0	4.7
Mean		0.10	0.103	0.23	0.05	0.66	0.05	44.0	6.0	2.1	7.6	2.9
Maximum		0.10	0.500	0.50	0.07	2.10	0.05	68.0	11.0	3.0	12.0	5.6
Minimum		0.10	0.005	0.10	0.05	0.10	0.05	20.0	1.0	1.0	2.0	1.3
Std. Dev		0.00	0.181	0.17	0.01	0.76	0.00	18.1	4.2	0.7	3.6	1.8
No. of D		1	0	3	4	5	0	7	7	0	7	7

Table 3-2. (Continued)

STATION	DATE	NH3	NO2	NO3	PO4	TKN	TP	TDS	TSS	BOD5	ALK	CHL_A
WA-7B	24-Apr	< 0.10	< 0.005	< 0.10	0.06	0.40	< 0.05	24.0	2.0	< 3.0	2.0	1.9
	23-May	< 0.10	< 0.005	0.30	0.06	0.20	< 0.05	12.0	< 1.0	< 3.0	6.0	2.9
	13-Jun	< 0.10	< 0.005	< 0.10	< 0.05	0.80	< 0.05	80.0	4.0	< 1.0	8.0	1.5
	18-Jul	< 0.10	< 0.005	0.30	< 0.05	0.60	< 0.05	60.0	3.0	< 2.0	7.0	27.4
	09-Aug	0.16	< 0.100	0.10	0.05	0.29	< 0.05	12.0	6.0	< 2.0	12.0	2.2
	27-Sep	< 0.10	< 0.100	< 0.10	0.05	< 0.20	< 0.05	66.0	16.0	< 2.0	8.0	9.7
	23-Oct	< 0.10	< 0.500	< 0.50	< 0.05	< 1.00	< 0.05	62.0	1.0	< 2.0	14.0	1.6
Mean		0.11	0.103	0.21	0.05	0.50	0.05	45.1	4.7	2.1	8.1	6.7
Maximum		0.16	0.500	0.50	0.06	1.00	0.05	80.0	16.0	3.0	14.0	27.4
Minimum		0.10	0.005	0.10	0.05	0.20	0.05	12.0	1.0	1.0	2.0	1.5
Std. Dev		0.02	0.181	0.16	0.00	0.31	0.00	28.3	5.3	0.7	3.9	9.6
No. of D		1	0	3	4	5	0	7	6	0	7	7

3.2.1 Ammonia

Ammonia in the water column of F.E. Walter Reservoir was consistently low throughout the monitoring period (Fig. 3-9). Concentrations at most stations and depths were less than the method detection limit (0.1 mg/L). Detectable amounts of ammonia were measured in most months but with one exception did not exceed 0.3 mg/L. In September the highest concentration was measured at downstream station WA-1. The concentration at WA-1 was 0.9-mg/L.

F.E. Walter Reservoir was in compliance with the PADEP water quality standard for ammonia during 2001. The water quality standard of ammonia is dependent on temperature and pH (Table 3-3). Throughout the monitoring period, all measures of ammonia were less than their respective criteria values.

A seasonal trend analysis of ammonia was conducted for individual stations of F.E. Walter Reservoir, combining 2001 and historical data. The Mann-Kendall statistic was applied to station data collected over the past 23 years or more, separately for spring (April to June) and summer (July to September) seasons. Stations included in the analysis represented locations downstream (WA-1), within the main reservoir (WA-2), and upstream sources on Tobyhanna Creek (WA-3), Lehigh River (WA-4), and Bear Creek (WA-5).

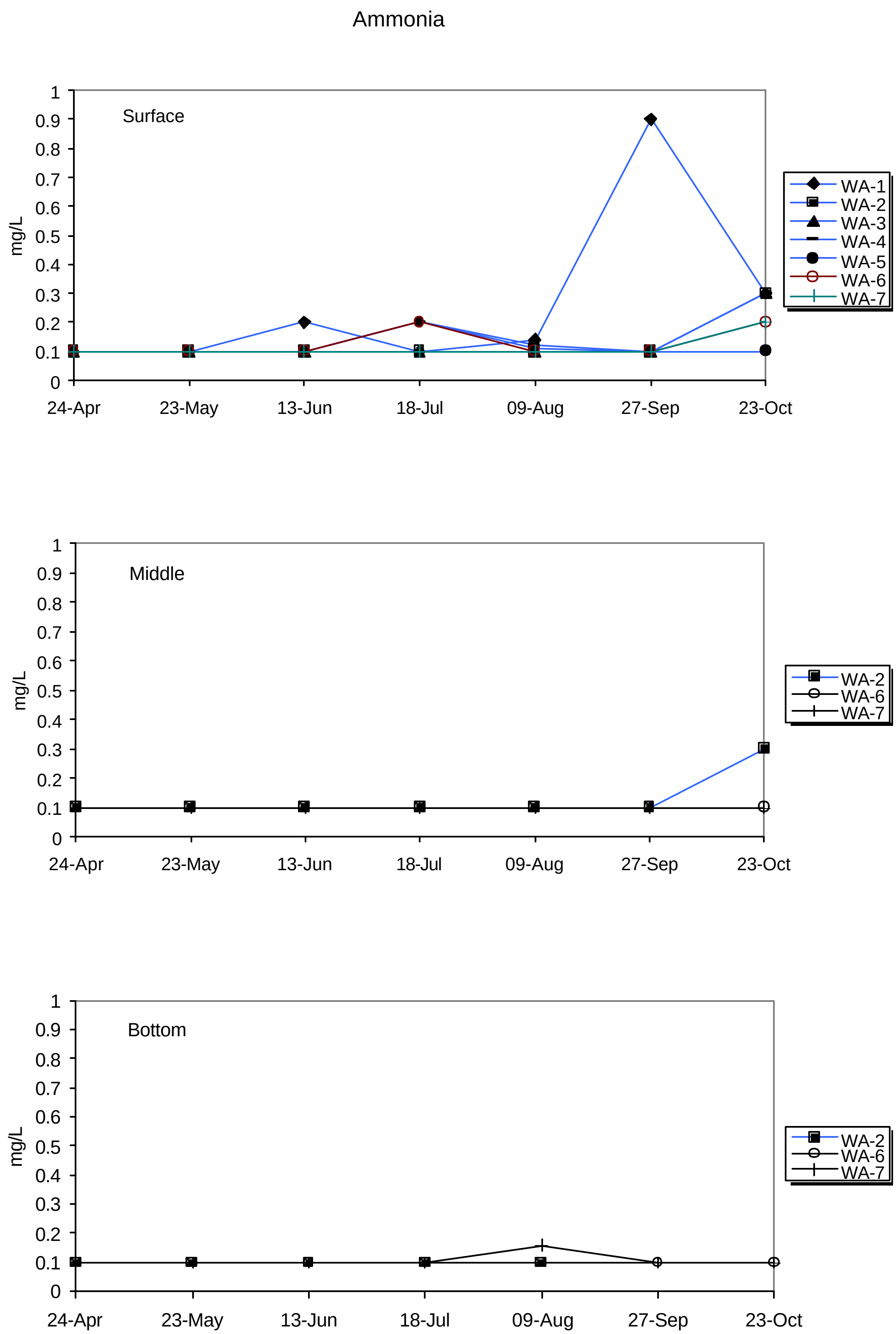

Figure 3-9. Ammonia measured in surface, middle, and bottom water of F. E. Walter Reservoir during 2001. The PADEP water quality standard for ammonia is dependent on temperature and pH.

Table 3-3. PADEP ammonia nitrogen criteria (Pennsylvania Code, Title 25 1984). Specific ammonia criteria dependent on temperature and pH.							
pH	**0 ?C**	**5 ?C**	**10 ?C**	**15 ?C**	**20 ?C**	**25 ?C**	**30 ?C**
6.50	25.5	25.5	25.5	17.4	12.0	8.4	5.9
6.75	23.6	23.6	23.6	16.0	11.1	7.7	5.5
7.00	20.6	20.6	20.6	14.0	9.7	6.8	4.8
7.25	16.7	16.7	16.7	11.4	7.8	5.5	3.9
7.50	12.4	12.4	12.4	8.5	5.9	4.1	2.9
7.75	8.5	8.5	8.5	5.8	4.0	2.8	2.0
8.00	5.5	5.5	5.5	5.8	4.0	2.8	2.0
8.25	3.4	3.4	3.4	2.3	1.6	1.2	0.9
8.50	2.0	2.0	2.0	1.4	1.0	0.7	0.6
8.75	1.2	1.2	1.2	0.9	0.6	0.5	0.4
9.00	0.8	0.8	0.8	0.5	0.4	0.3	0.3

Ammonia concentrations appear to have decreased throughout the reservoir drainage area during both seasons. All but one of the stations, WA-5, had significant trends and reflected yearly decreases ranging from 0.002 to 0.007 mg/L (Table 3-4). In general, summer rates of decrease appeared to be slightly higher than for spring. The widespread trends appear to be driven by higher concentrations detected in the late 1970s; subsequently, most concentrations have been consistently lower at about 0.01 mg/L.

Table 3-4. Seasonal trends of ammonia concentration at individual stations of F.E. Walter Reservoir calculated with the Mann-Kendall Statistic. Shaded values are significant (at least P<0.05).					
Station	**# of Years**	**Spring**		**Summer**	
	spring/summer	**P Level**	**Rate (mg/)**	**P Level**	**Rate (mg/L)**
Surface Water					
WA-1	26	<0.01	-0.002	<0.001	-0.007
WA-2	27	<0.01	-0.003	<0.01	-0.004
WA-3	26	<0.01	-0.002	<0.01	-0.003
WA-4	27	<0.01	-0.002	<0.001	-0.002
WA-5	23	NS	-0.001	NS	-0.0005

3.2.2 Nitrite and Nitrate

Concentrations of nitrite in the water column of F.E. Walter Reservoir were consistently low during 2001. Concentrations of nitrite measured at all stations and all depths were less than method detection limits (0.5 mg/L) throughout the monitoring period (Fig. 3-10).

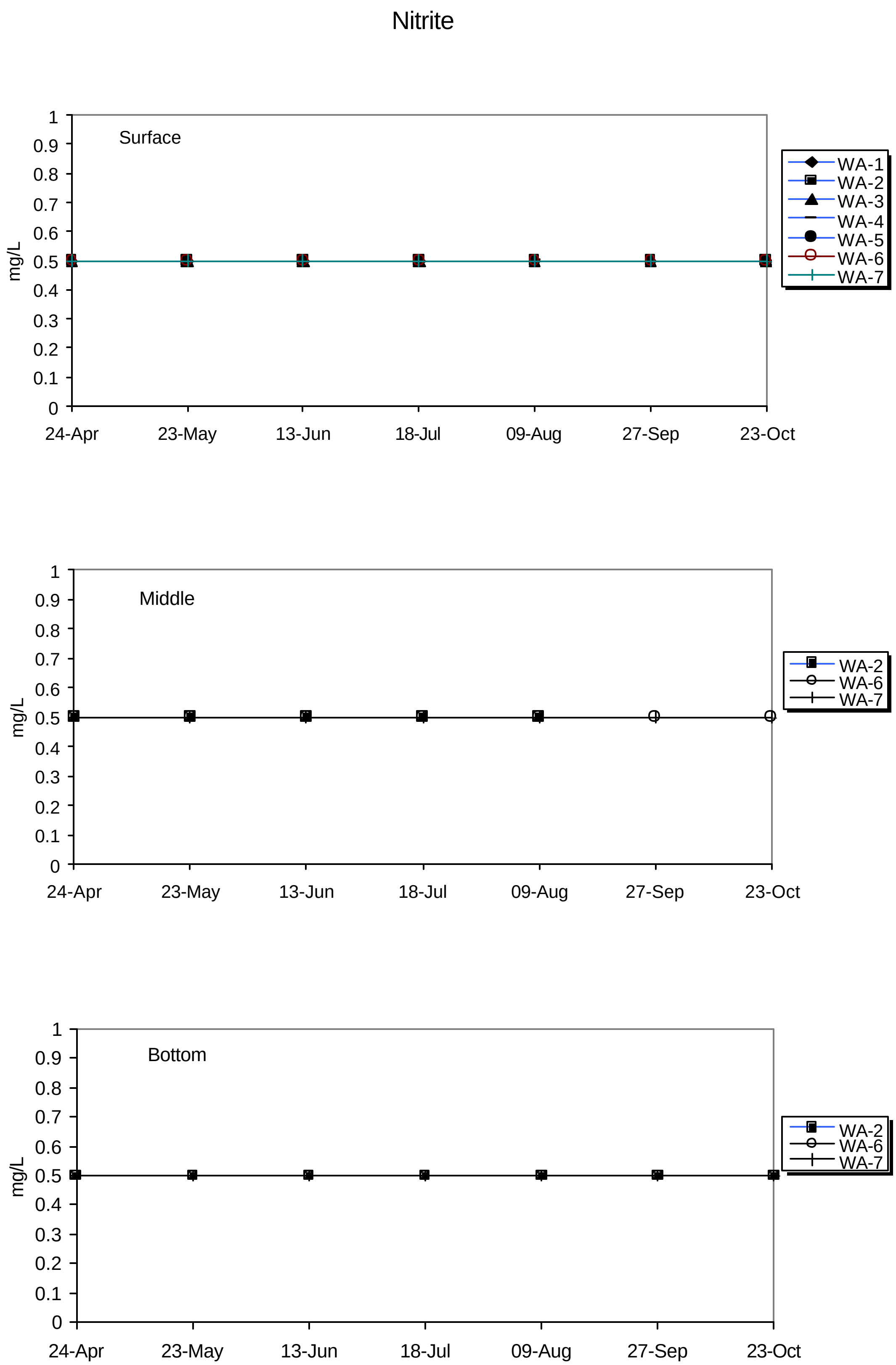

Figure 3-10. Nitrite measured in surface, middle, and bottom water of F. E. Walter Reservoir during 2001

Nitrate was distributed uniformly in the water column of F.E. Walter Reservoir during 2001 (Fig. 3-13). At most stations and depths, concentrations ranged from less than the method detection limit (0.1-mg/L) to 1.2-mg/L. Overall, concentrations averaged 0.2-mg/L throughout the monitoring period. Concentrations of nitrate upstream of the reservoir on Bear Creek (WA-5) were usually highest and over the monitoring period. averaging 0.3-mg/L and ranging from 0.1 to 1.1-mg/L. Nitrate measured downstream of the reservoir (BZ-1) was consistently low over the monitoring period at 0.2-mg/L.

In 2001, F.E. Walter Reservoir was in compliance with the PADEP water quality standard for nitrogen. The water quality standard for nitrogen is a summed concentration of nitrite and nitrate of less than 10-mg/L. Throughout the monitoring period, the summed concentrations for each station were less than 1.5-mg/L.

3.2.3 Total Inorganic Nitrogen

Concentrations of total inorganic nitrogen measured in 2001 and historical data collected from over the past 27 years were analyzed for seasonal trends (Figs. 3-12 and 3-13). The trend analysis was conducted for spring (April through June) and summer (July through October) periods, separately for stations representative of the reservoir and downstream. Concentrations of nitrogen have decreased in the reservoir and downstream during the summer (Fig. 3-13). Both regression lines were significant (R^2=0.19 and 0.17, respectively; $P<0.05$), and corresponded to an average 10-year decrease of approximately 0.02 mg/L. The trend analyses conducted for reservoir and downstream stations in the spring season were not significant (Fig. 3-12).

A seasonal trend analysis of total nitrogen was conducted for individual stations of F.E. Walter Reservoir, combining 2001 and historical data. The Mann-Kendall statistic was applied to station data collected over the past 22 years or more, separately for spring (April to June) and summer (July to September) seasons. Stations included in the analysis represented locations downstream (WA-1), within the main reservoir (WA-2), and upstream sources on Tobyhanna Creek (WA-3), Lehigh River (WA-4), and Bear Creek (WA-5).

Nitrogen concentrations appear to have decreased at several stations in the spring and summer seasons. Significant reductions were observed at stations WA-1 and WA-2 in the spring season (Table 3-5). Nitrogen reductions ranged from 0.007 to 0.009 mg/L during the spring season. Significant reductions were also observed at stations WA-1 and WA-4 during the summer season (Table 3-5). Nitrogen reductions ranged from 0.007 to 0.009 mg/L during the summer season.

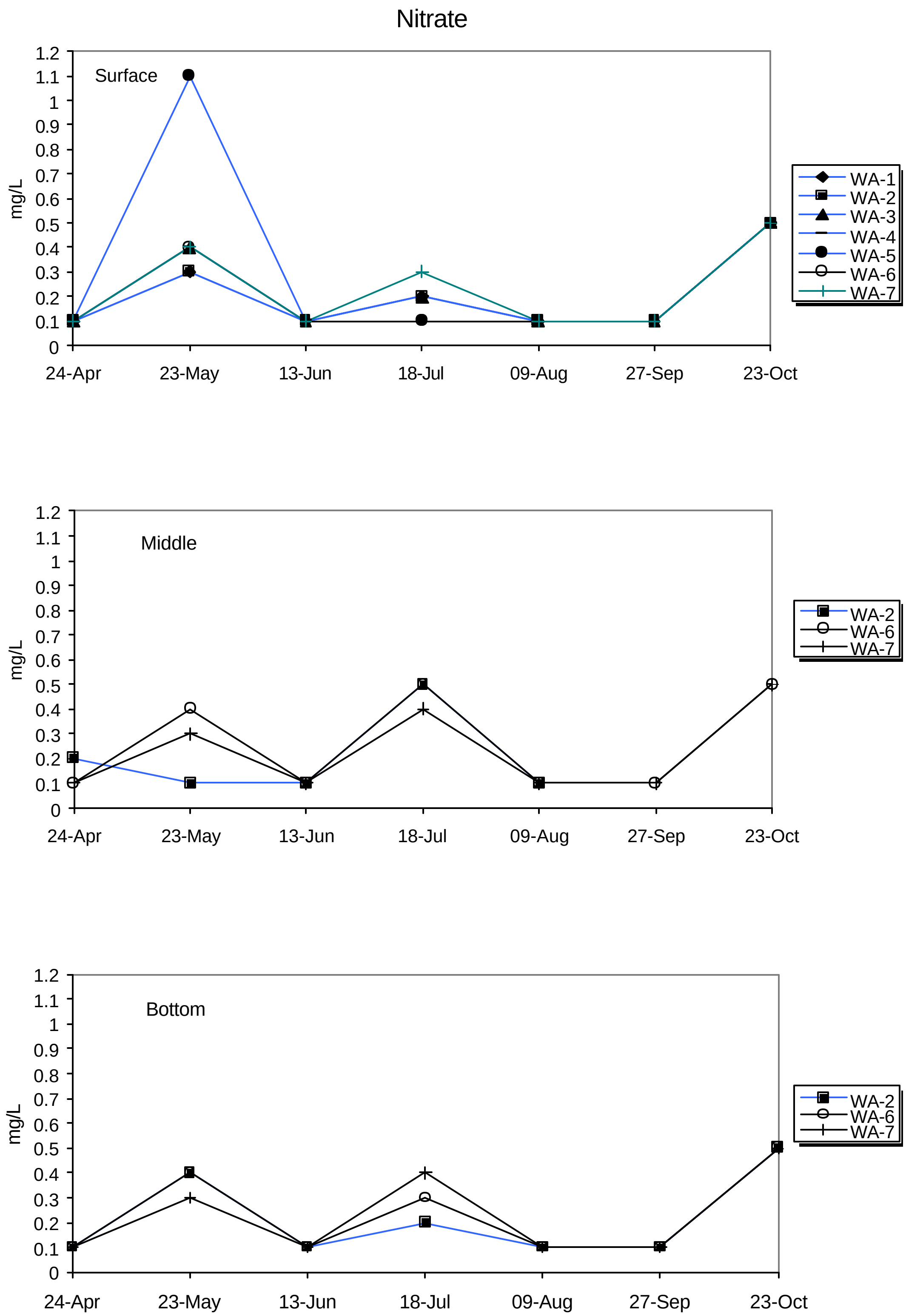

Figure 3-11. Nitrate measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2001

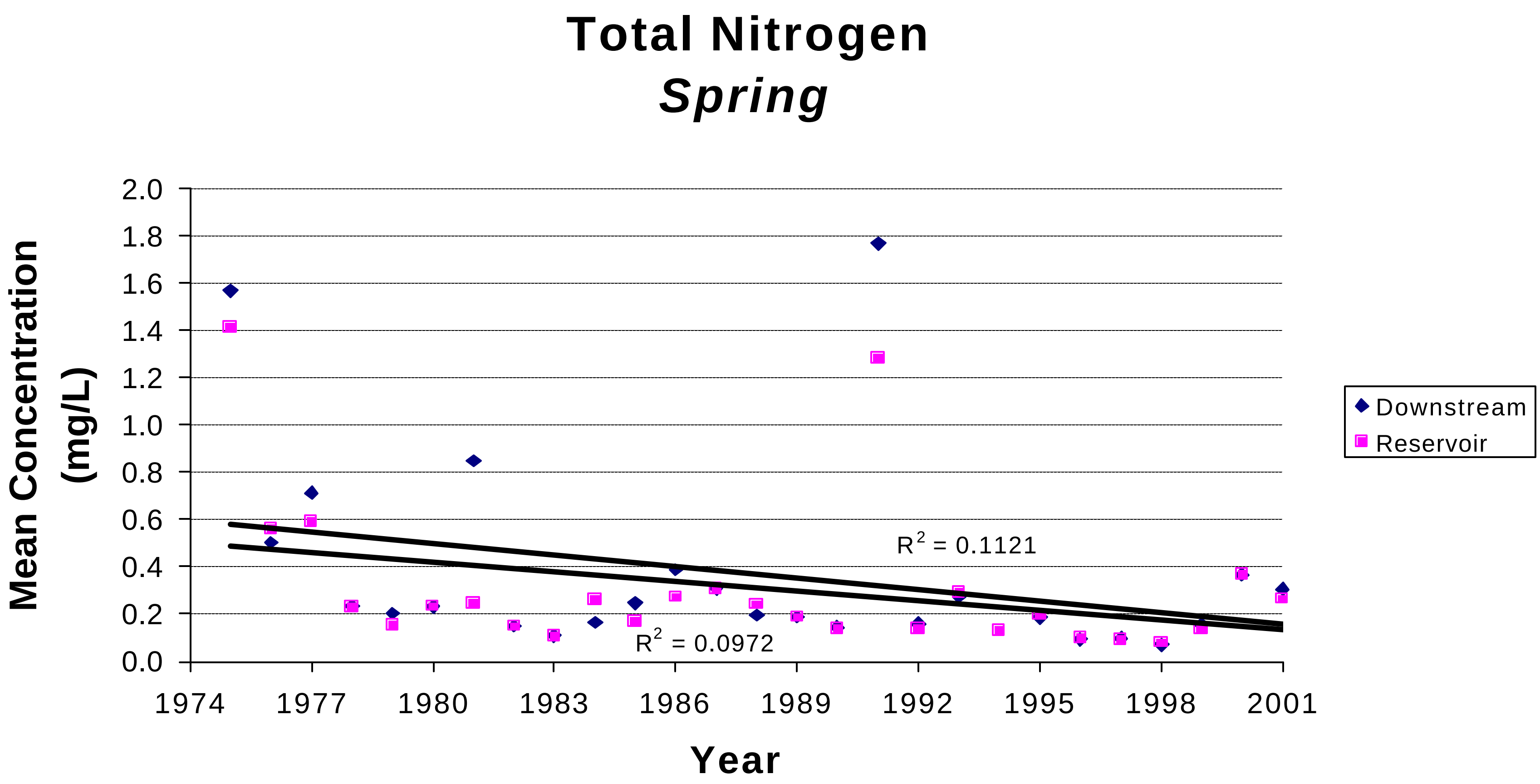

Figure 3-12. Seasonal trend analysis for total nitrogen (ammonia+nitrite+nitrate) measured during spring months (April, May, and June) at F. E. Walter Reservoir

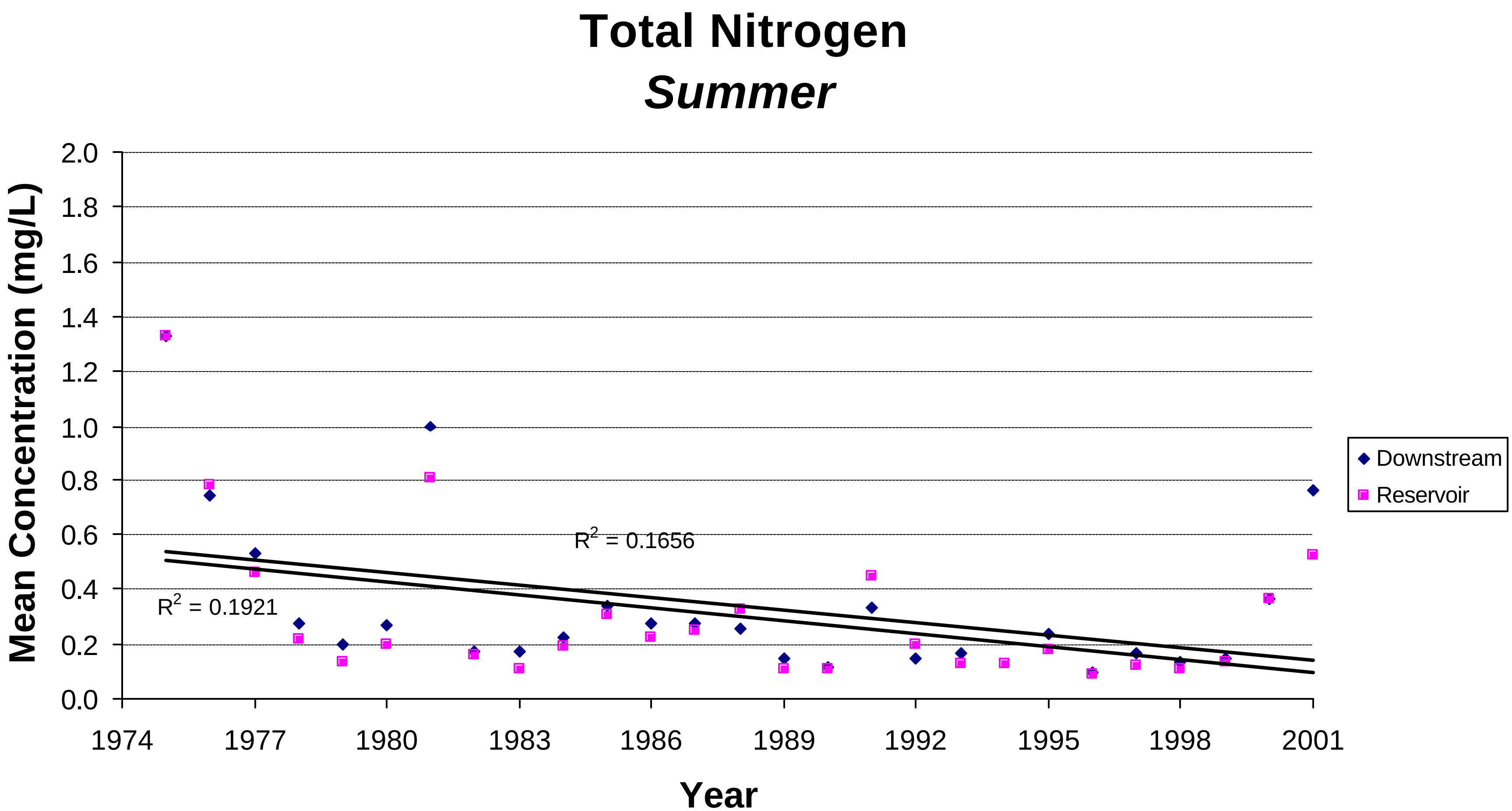

Figure 3-13. Seasonal trend analysis for total nitrogen (ammonia+nitrite+nitrate) measured during summer months (July, August, and September) at F.E. Walter Reservoir

Table 3-5. Seasonal trends of total nitrogen concentration at individual stations of F.E. Walter Reservoir calculated with the Mann-Kendall Statistic. Shaded values are significant (at least P<0.05).					
Station	**# of Years spring/summer**	**Spring**		**Summer**	
		P Level	**Rate (mg/L)**	**P Level**	**Rate (mg/L)**
Surface Water					
WA-1	**25/26**	<0.05	-0.009	<0.05	-0.009
WA-2	**26/27**	<0.05	-0.007	NS	-0.005
WA-3	25/26	NS	-0.006	NS	-0.007
WA-4	26/27	NS	-0.007	<0.05	-0.007
WA-5	22/23	NS	-0.003	NS	-0.0008

3.2.4 Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen (TKN) is a measure of organic nitrogen that includes ammonia. TKN in the water column of F.E. Walter Reservoir was generally low during 2001 (Fig. 3-14). Concentrations measured at most stations and depths were near or less than the method detection limit of 0.2 mg/L throughout the monitoring period. The highest concentrations were measured in June and ranged to 1.95-mg/L in surface water at station WA-2 and 1.45-mg/L in middle water at station WA-2.

3.2.5 Dissolved Phosphate

Dissolved phosphate was not a significant nutrient parameter at F.E. Walter Reservoir in 2001 (Fig. 3-15) Concentrations of dissolved phosphate were generally at or below the detection limit of 0.05-mg/L. One isolated instance of high values was recorded, in June at WA-2 in the surface water. This concentration was 0.38 and 11-mg/L. In freshwater environments, dissolved phosphate is usually a limiting nutrient and is readily taken up by freshwater plants and algae.

3.2.6 Total Phosphorus

Total phosphorus was not present at measurable concentrations in the water column of F.E. Walter Reservoir during 2001 (Fig. 3-16). All concentrations were less than the method detection limit of 0.05-mg/L. EPA guidance for nutrient criteria in lakes and reservoirs suggests a minimum concentration for total phosphorus of 0.01-mg/L (EPA 2000), a concentration 5-times less than our ability to detect. Lakes and reservoirs exceeding this concentration are more likely to experience algal bloom problems during the growing season.

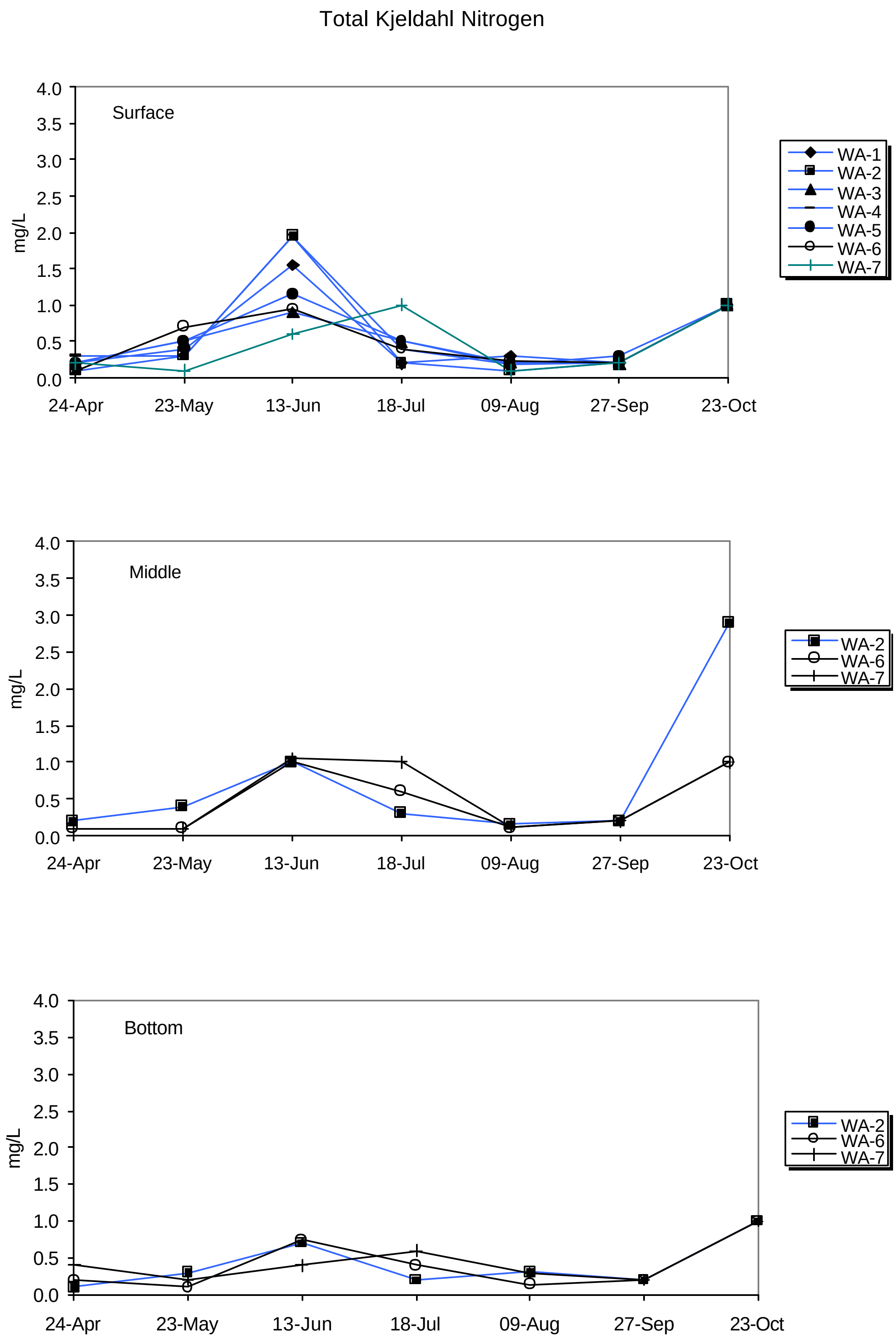

Figure 3-14. Total Kjeldahl nitrogen measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2001

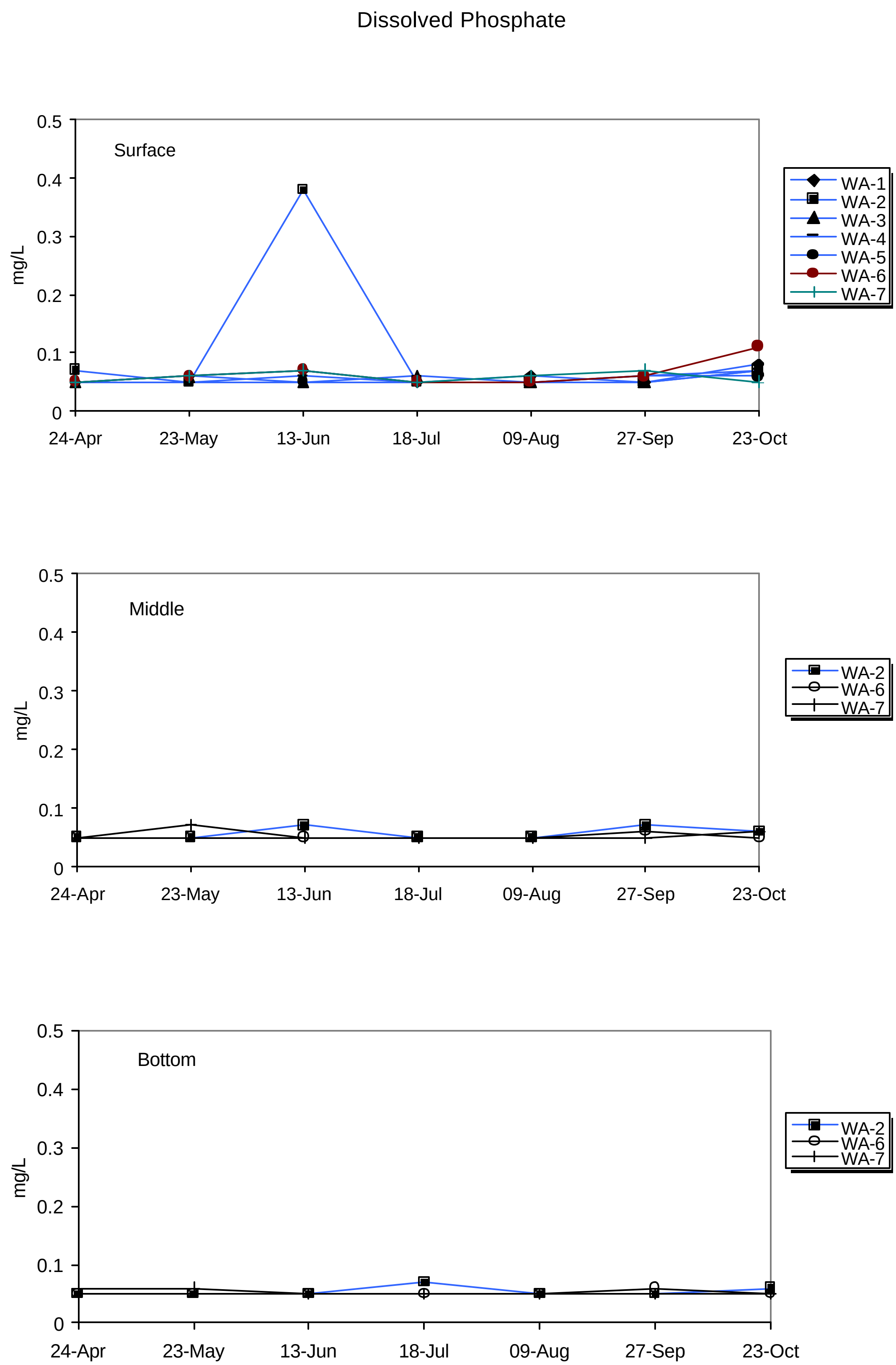

Figure 3-15. Dissolved phosphate measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2001

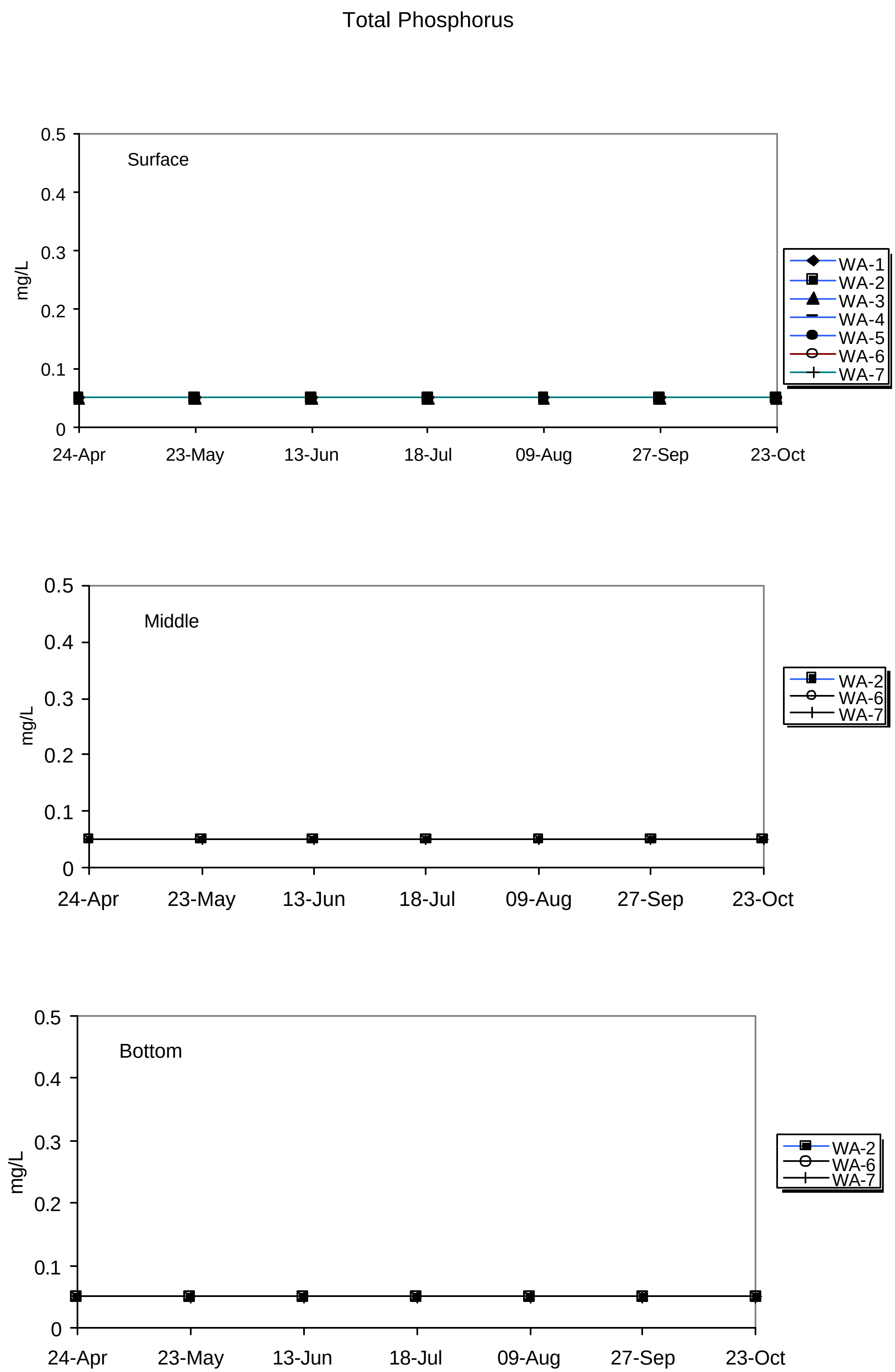

Figure 3-16. Total phosphorus measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2001

Concentrations of total phosphorus measured in 2001 and historical data collected over the past 22 years were analyzed for seasonal trends using regression. The trend analysis was conducted for spring and summer periods, separately for stations representative of the reservoir and downstream. No trends were determined for either of the reservoir or downstream locations (Figs. 3-17 and 3-18). None of the regressions were significant (P>0.05).

A seasonal trend analysis of total phosphorus was also conducted for individual stations of F.E. Walter Reservoir, combining 2001 and historical data. The Mann-Kendall statistic was applied to station data collected over the past 20 years or more, separately for spring (April to June) and summer (July to September) seasons. Stations included in the analysis were representative of locations downstream (WA-1), within the main reservoir (WA-2), and upstream sources on Tobyhanna Creek (WA-3), Lehigh River (WA-4), and Bear Creek (WA-5). Based on this analysis, no significant trends were apparent for individual stations (Table 3-6).

Table 3-6. Seasonal trends of total phosphorus concentration at individual stations of F.E. Walter Reservoir calculated with the Mann-Kendall Statistic.

Station	**# of Years**	**Spring**		**Summer**	
		P Level	**Rate (mg/L)**	**P Level**	**Rate (mg/L)**
Surface Water					
WA-1	21	NS	-0.95	NS	0.16
WA-2	22	NS	-0.27	NS	-0.17
WA-3	21	NS	-0.57	NS	0.23
WA-4	22	NS	-0.21	NS	-0.26
WA-5	22	NS	0.10	NS	0.0

3.2.7 Total Dissolved Solids

Total dissolved solids (TDS) in the water column of F.E. Walter Reservoir throughout, followed a similar pattern during 2001. Concentrations at all stations and depths averaged 51-mg/L over the monitoring period while ranging from 10 to 100-mg/L (Fig. 3-19). Higher concentrations were measured at station WA-2 in the middle and bottom waters in October. In that month, the concentration of TDS in the middle water was 164-mg/L while that in the bottom water was 146-mg/L.

F.E. Walter Reservoir was in compliance with the PADEP water quality standard for total dissolved solids during 2001. The water quality standard is a maximum concentration of 500-mg/L. Throughout the monitoring period, concentrations measured at all stations were always three times less than the standard.

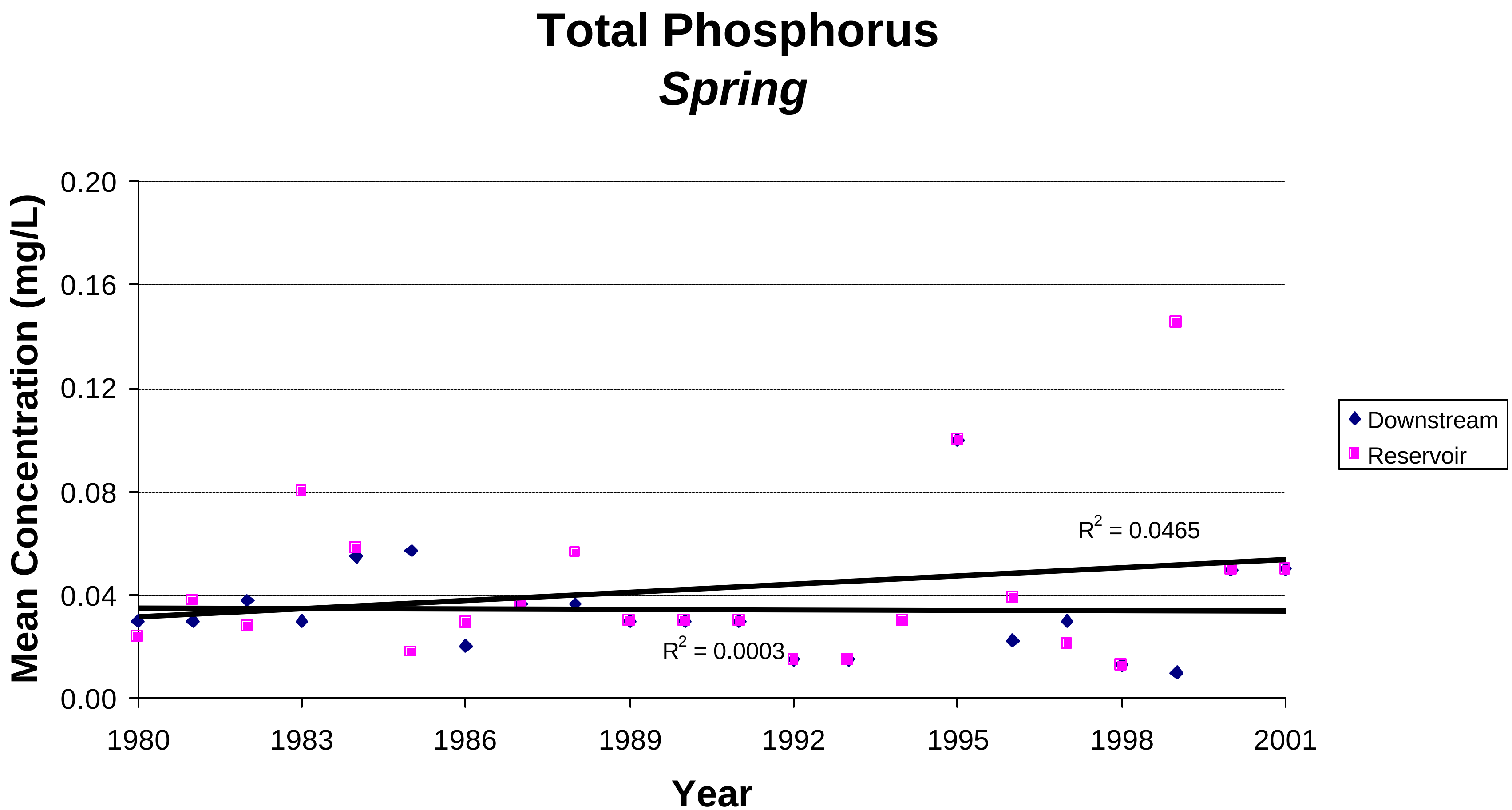

Figure 3-17. Seasonal trend analysis for total phosphorus measured during spring months (April, May, and June) at F.E. Walter Reservoir

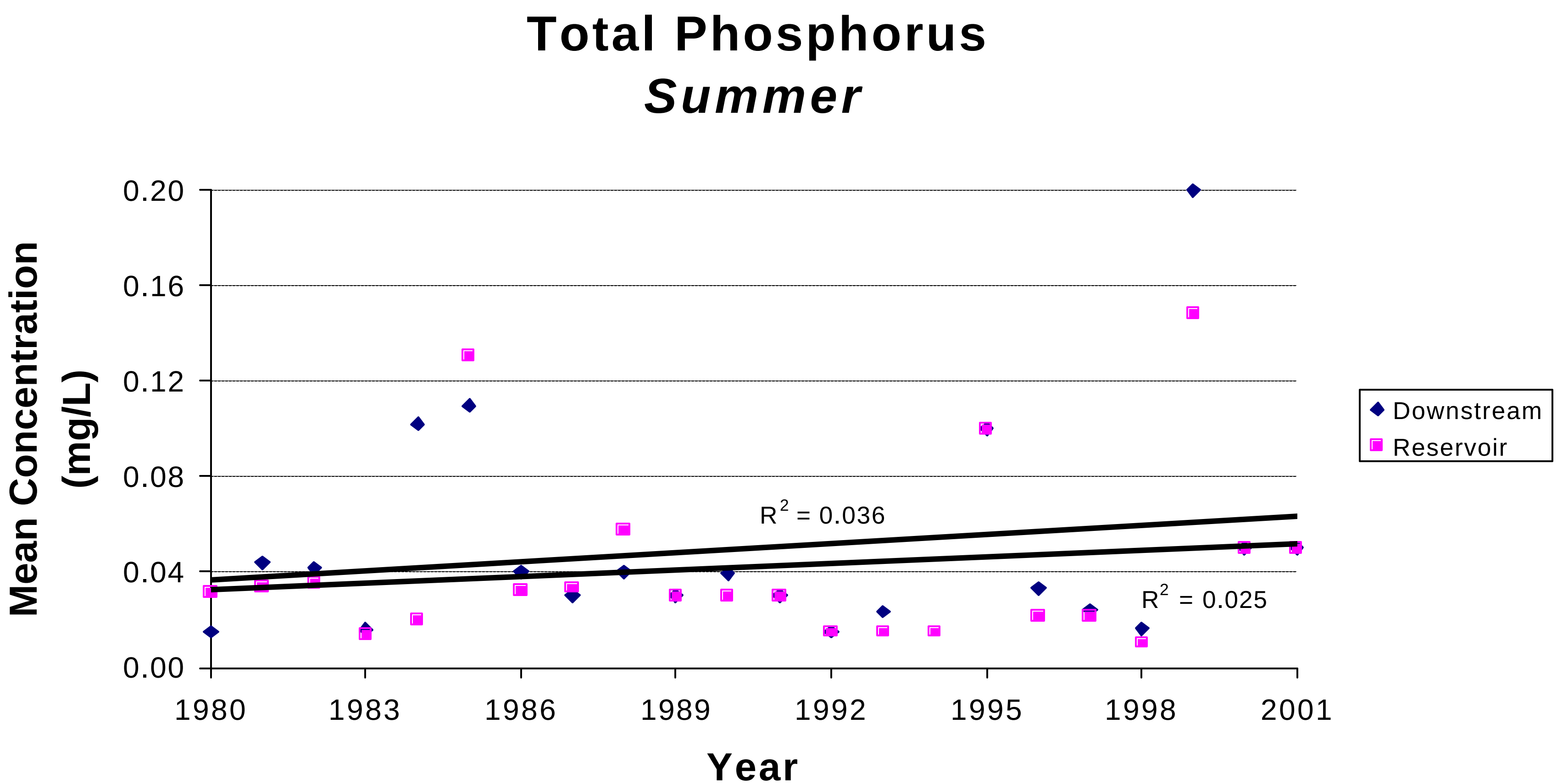

Figure 3-18. Seasonal trend analysis for total phosphorus measured during summer months (July, August, and September) at F.E. Walter Reservoir

Concentrations of total dissolved solids measured in 2001 and historical data collected over the past 26 years were analyzed for seasonal trends. The trend analysis was conducted for spring and summer periods, separately for stations representative of the reservoir and downstream. TDS concentrations at F.E. Walter Reservoir have not changed consistently over the time series (Fig. 3-21 and 3-22). No significant trends were identified by the regression analyses (P>0.05) for either season at reservoir and downstream stations.

TDS concentrations measured in 2001 were higher than in prior years of monitoring. Seasonal averages calculated for this year's data plotted above the regression for both reservoir and downstream locations.

A seasonal trend analysis of TDS was also conducted for individual stations of F.E. Walter Reservoir combining 2001 and historical data. The Mann-Kendall statistic was applied to station data collected over the past 23 years or more, separately for spring (April to June) and summer (July to September) seasons. Stations included in the analysis represented: downstream (WA-1), main reservoir (WA-2), and upstream sources on Tobyhanna Creek (WA-3), Lehigh River (WA-4), and Bear Creek (WA-5). Based on this analysis, no significant trends were apparent for individual stations (Table 3-7).

Table 3-7. Seasonal trends of total dissolved solids concentration at individual stations of F.E. Walter Reservoir calculated with the Mann-Kendall Statistic.

Station	# of Years spring/summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate (mg/L)
Surface Water					
WA-1	26	NS	-0.25	NS	-0.22
WA-2	27	NS	-0.44	NS	-0.29
WA-3	26	NS	0.46	NS	0.01
WA-4	27	NS	0.19	NS	0.11
WA-5	23	NS	-0.37	NS	0.67

3.2.8 Total Suspended Solids

Total suspended solids (TSS) in the water column of F.E. Walter Reservoir were consistently low in 2001. For the most part, concentrations measured throughout the reservoir ranged less than 10 mg/L (Fig. 3-24). Overall concentrations at stations and all depths averaged 5.6-mg/L and ranged from 1 to 38-mg/L (Fig. 3-23).

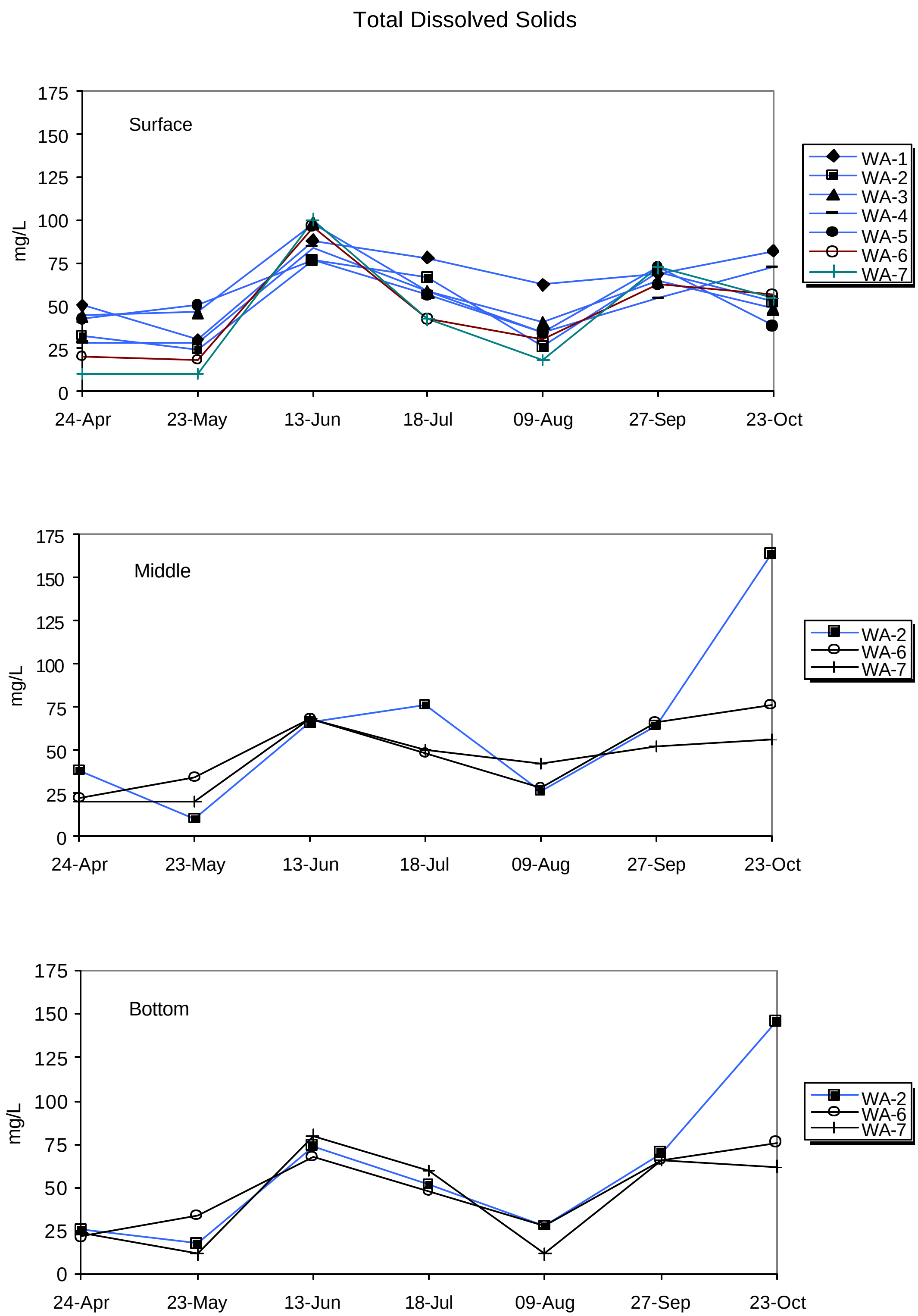

Figure 3-19. Total dissolved solids measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2001. The PADEP water quality standard for TDS is a maximum concentration of 500 mg/L.

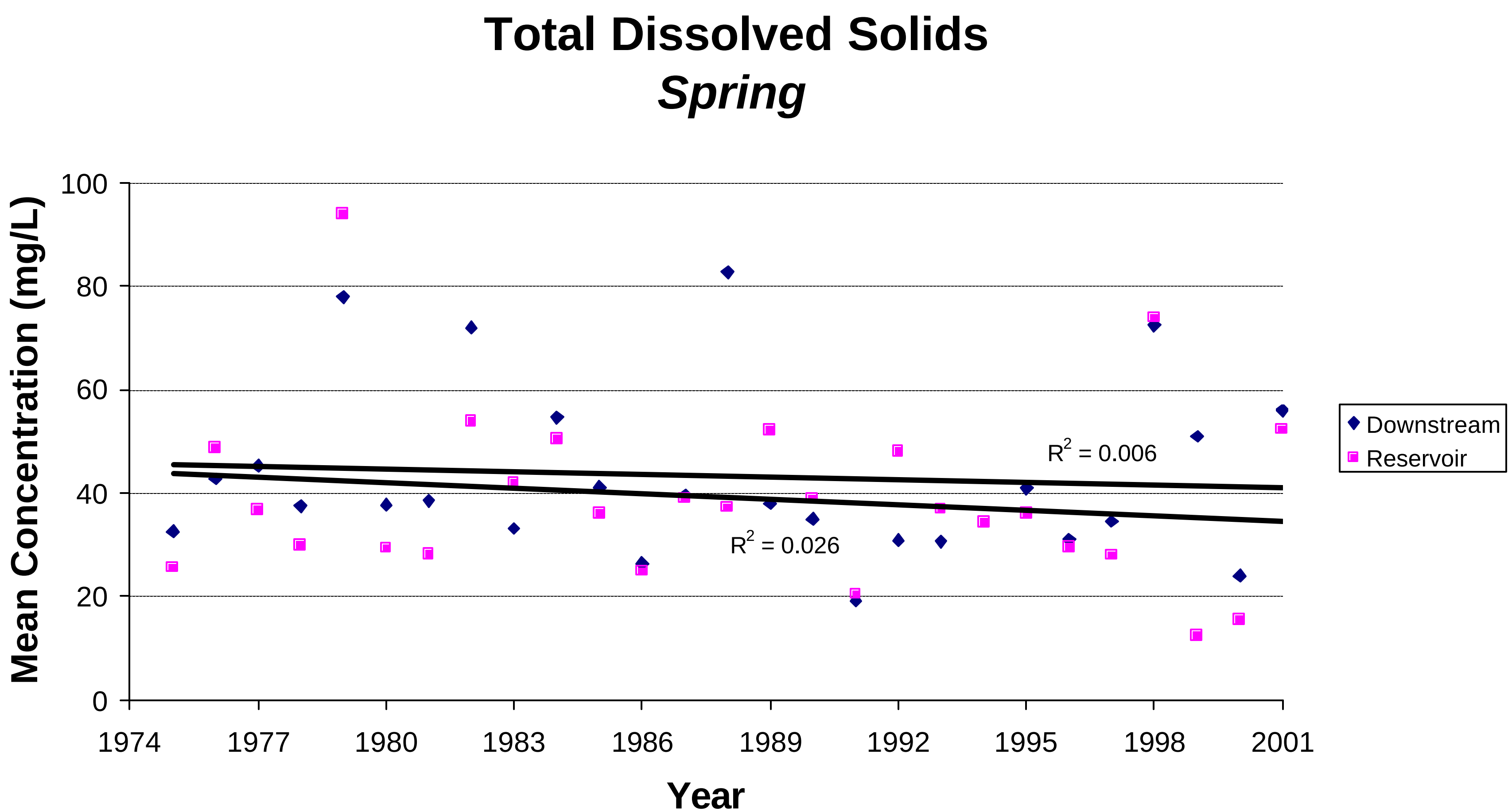

Figure 3-20. Seasonal trend analysis for total dissolved solids measured during spring months (April, May, and June) at F.E. Walter Reservoir

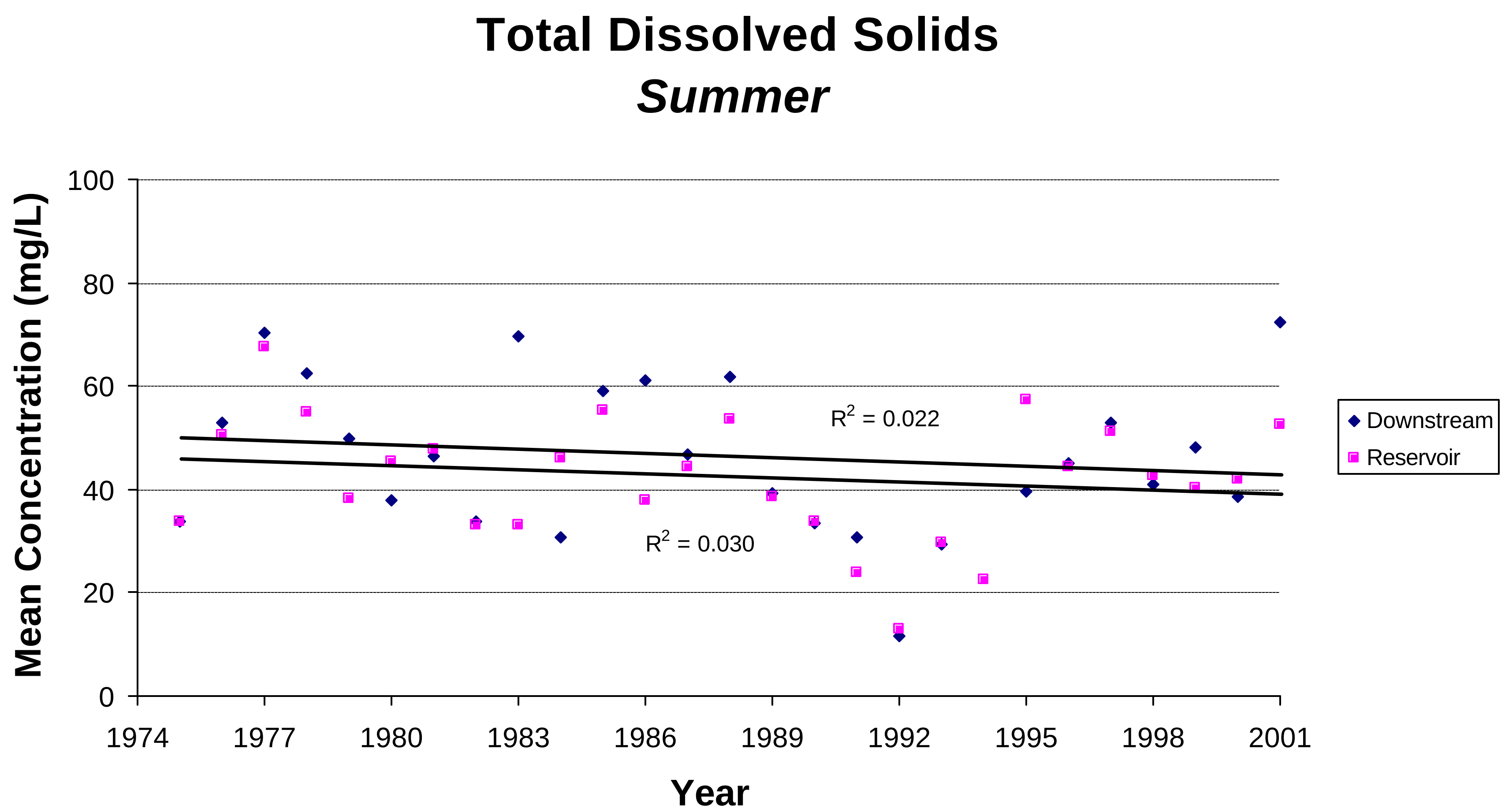

Figure 3-21. Seasonal trend analysis for total dissolved solids measured during summer months (July, August, and September) at F.E. Walter Reservoir

3.2.9 Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) in the water column of F.E. Walter Reservoir was consistently low during 2001. Concentrations measured at all stations and depths were always less than method detection limits (between 1and 3-mg/L) throughout the monitoring period (Fig. 3-22).

Concentrations of BOD measured in 2001 and historical data collected from over the past 22 years were analyzed for seasonal trends. The trend analysis was conducted for spring and summer periods, separately, for stations representative of the reservoir and downstream. No seasonal trends were determined for either of the reservoir and downstream locations (Fig. 3-23 and 3-24). None of the regressions were significant (P>0.05). The analyses; however, has probably been confounded by low concentrations measured in recent years. Since 1995, the seasonal averages at both locations have been near or less than the method detection limits which ranged from 2 to 4-mg/L.

A seasonal trend analysis of BOD was also conducted for individual stations of F.E. Walter Reservoir combining 2001 and historical data. The Mann-Kendall statistic was applied to station data collected over the past 20 years or more, separately, for spring (April to June) and summer (July to September) seasons. Stations included in the analysis were representative of locations downstream (WA-1), within the reservoir (WA-2), and upstream sources on Tobyhanna Creek (WA-3), Lehigh River (WA-4), and Bear Creek (WA-5). Based on this analysis, no significant trends were identified for individual stations (Table 3-8).

Table 3-8. Seasonal trends of BOD concentration at individual stations of F.E. Walter Reservoir calculated with the Mann-Kendall Statistic.

Station	# of Years spring/summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate (mg/L)
Surface Water					
WA-1	20	NS	-0.025	NS	-0.008
WA-2	21	NS	-0.046	NS	-0.017
WA-3	20	NS	-0.012	NS	0.000
WA-4	21	NS	-0.018	NS	0.000
WA-5	21	NS	0.000	NS	0.000

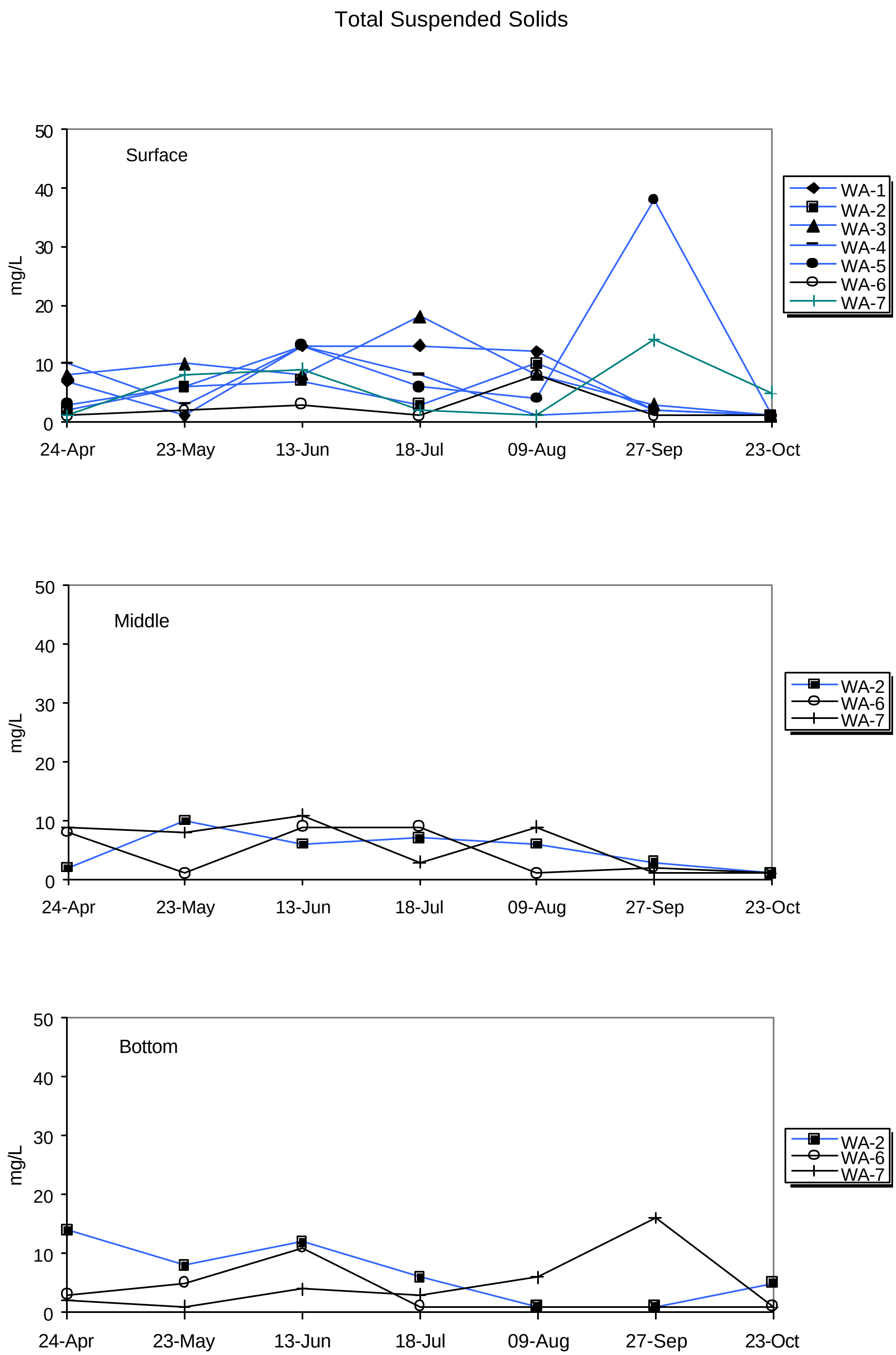

Figure 3-22. Total suspended solids measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2001

Biochemical Oxygen Demand

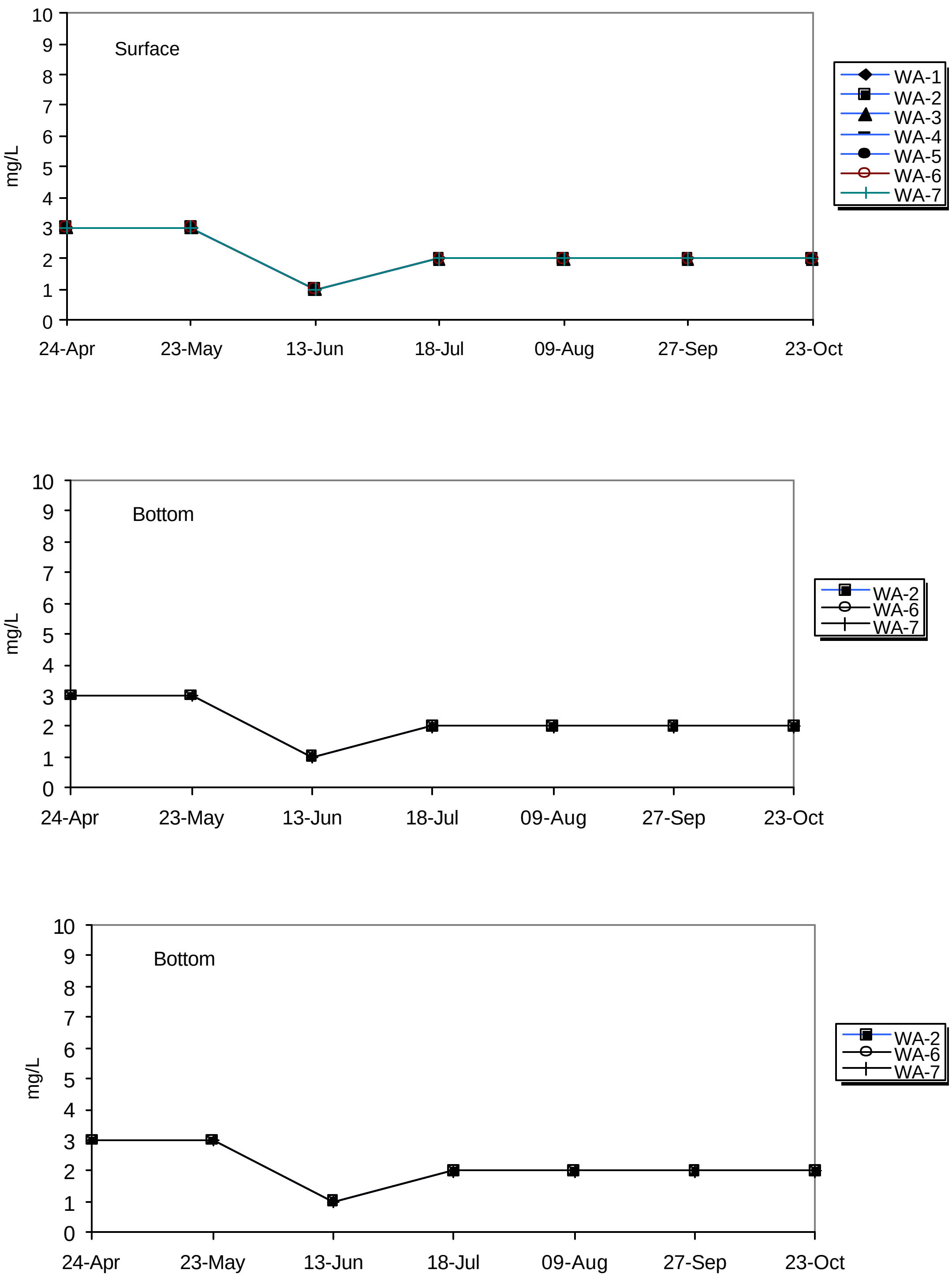

Figure 3-23. Biochemical oxygen demand (5-day) measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2001

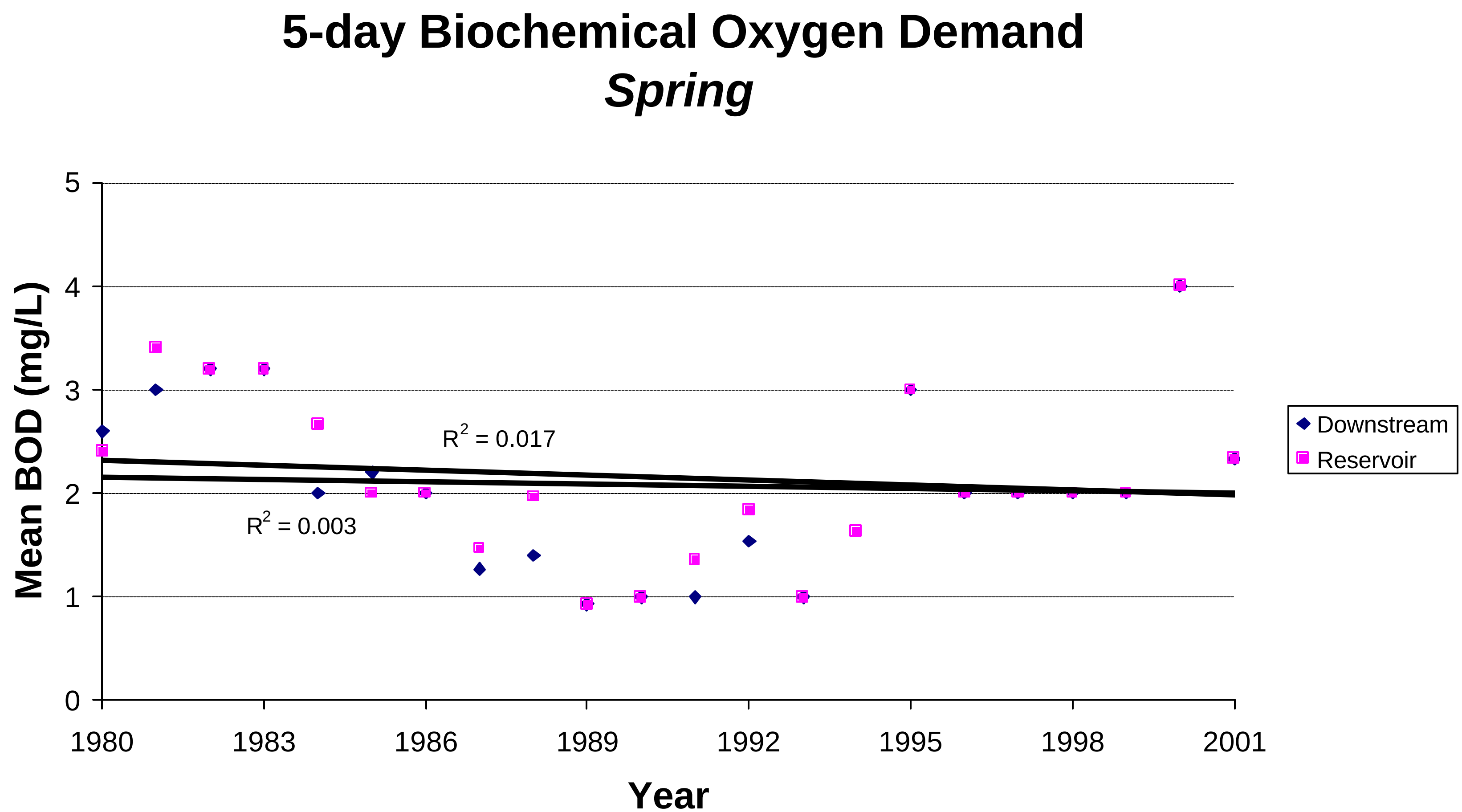

Figure 3-24. Seasonal trend analysis for biochemical oxygen demand (5-day) measured during spring months (April, May, and June) at F.E. Walter Reservoir

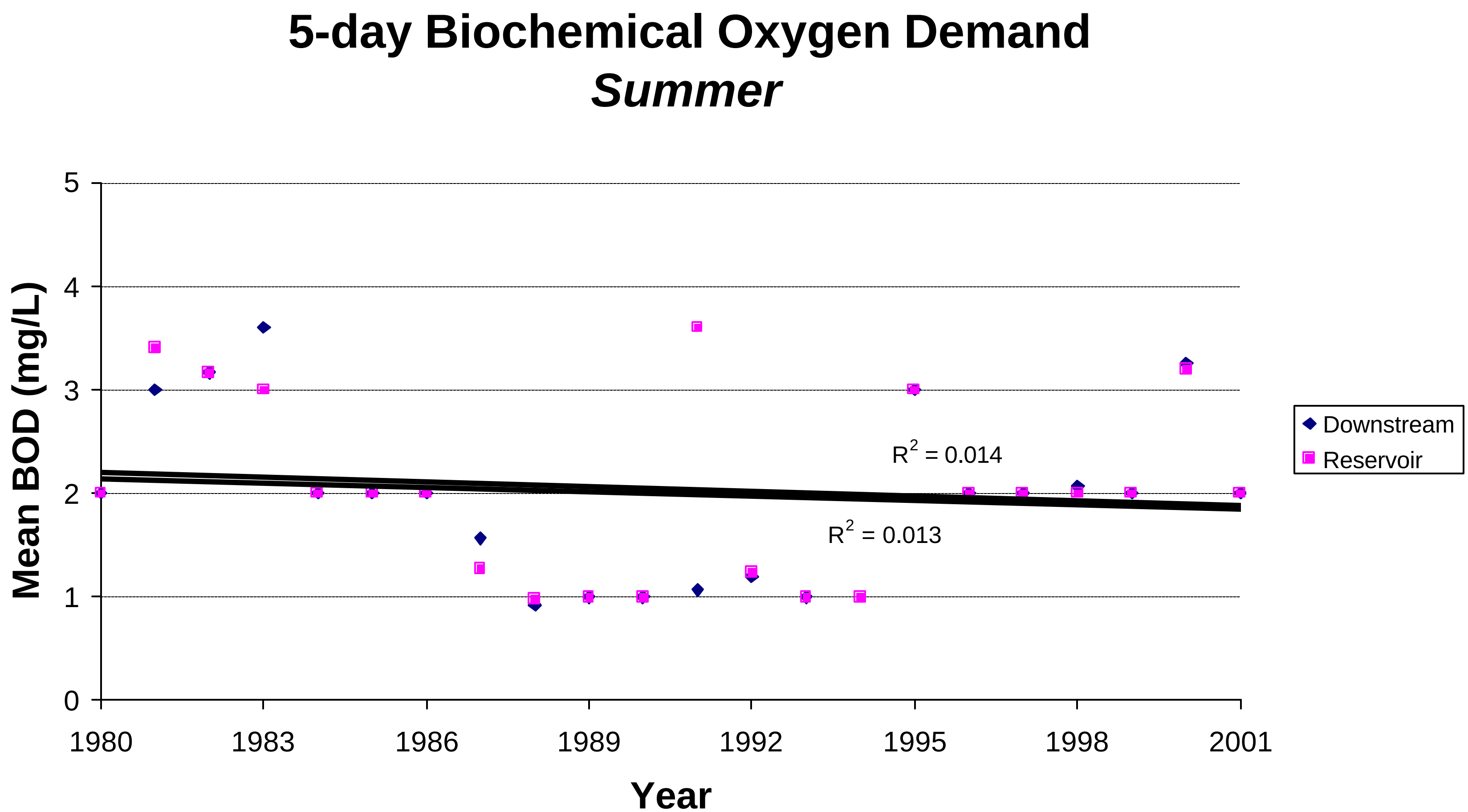

Figure 3-25. Seasonal trend analysis for biochemical oxygen demand (5-day) measured during summer months (July, August, and September) at F.E. Walter Reservoir

3.2.10 Alkalinity

Alkalinity in the waters of F.E. Walter Reservoir was very low during 2001. Concentrations measured at all stations and depths averaged 7.2-mg/L and ranged less than 18 mg/L throughout the monitoring period (Fig. 3-26). Alkalinity is a measure of the acid-neutralizing capacity of water. The PADEP standard is a minimum concentration of 20 mg/L $CaCO_3$ except where natural conditions are less. The natural alkalinity of water is largely dependent on the underlying geology and soils within the surrounding watershed. The low alkalinity measured at F.E. Walter Reservoir probably results from the regional geology which is primarily sandstone and shale (Van Diver 1990).

3.2.11 Total Inorganic and Organic Carbon

Total inorganic carbon in the water column of Beltzville Reservoir was not present in measurable concentrations during 2001 at most stations (Fig. 3-27). With the exception of WA-1 in June, all concentrations measured were less than the method detection limits of 1 and 5-mg/L. The concentration at WA-1 in June was 3-mg/L.

Total organic carbon in the waters of F.E. Walter Reservoir was very low during 2001. Concentrations measured at all stations and depths averaged 4.6-mg/L and ranged from less than the method detection limits of 1 and 5-mg/L to 8-mg/L throughout the monitoring period (Fig. 3-28).

3.2.12 Chlorophyll *a*

For the most part, chlorophyll *a* was low in the water column of F.E. Walter Reservoir during 2001 (Fig. 3-29). Concentrations at all stations and depths averaged 3.5 mg/m^3 and generally ranged up to 10-mg/m^3 throughout the monitoring period. A higher concentration; however, was measured in the lower water column of the reservoir at station WA-7. The concentration at WA-7 during July was 27.4 mg/m^3.

3.3 TROPHIC STATE DETERMINATION

Carlson's (1977) trophic state index (TSI) is a method of expressing the extent of eutrophication of a lake, quantitatively. The trophic state analysis calculates separate indices for eutrophication based on measures of total phosphorus, chlorophyll *a*, and secchi disk depth. Index values for each parameter range on the same scale from 0 (least enriched) to 100 (most enriched). The resulting indices can also be compared to qualitative threshold values that correspond to levels of eutrophication: mesotrophic (TSI < 40), mesoeutrophic (TSI's from 50 to 60), and eutrophic (TSI > 60).

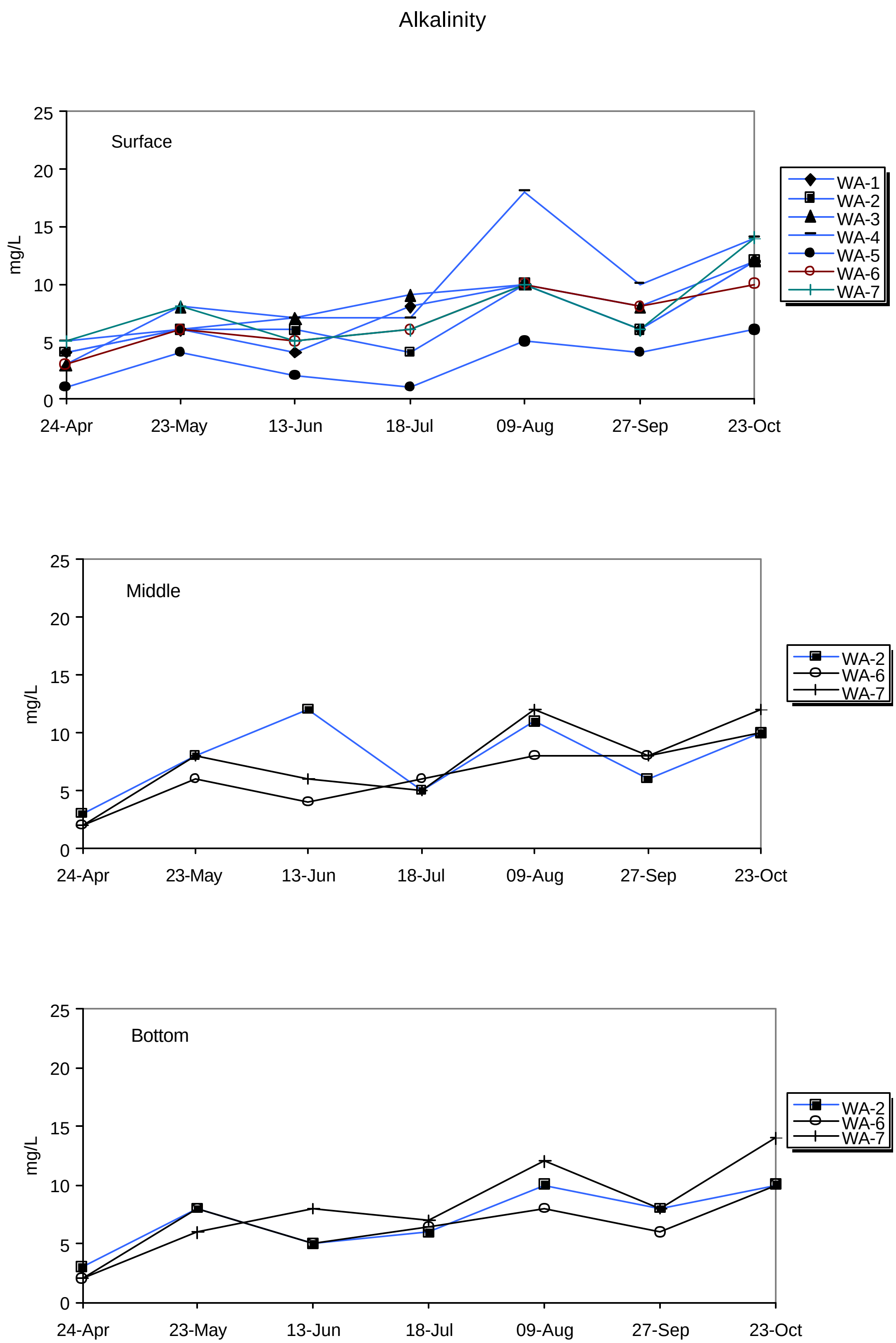

Figure 3-26. Alkalinity measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2001. The PADEP water quality standard for alkalinity is a minimum concentration of 20 mg/L.

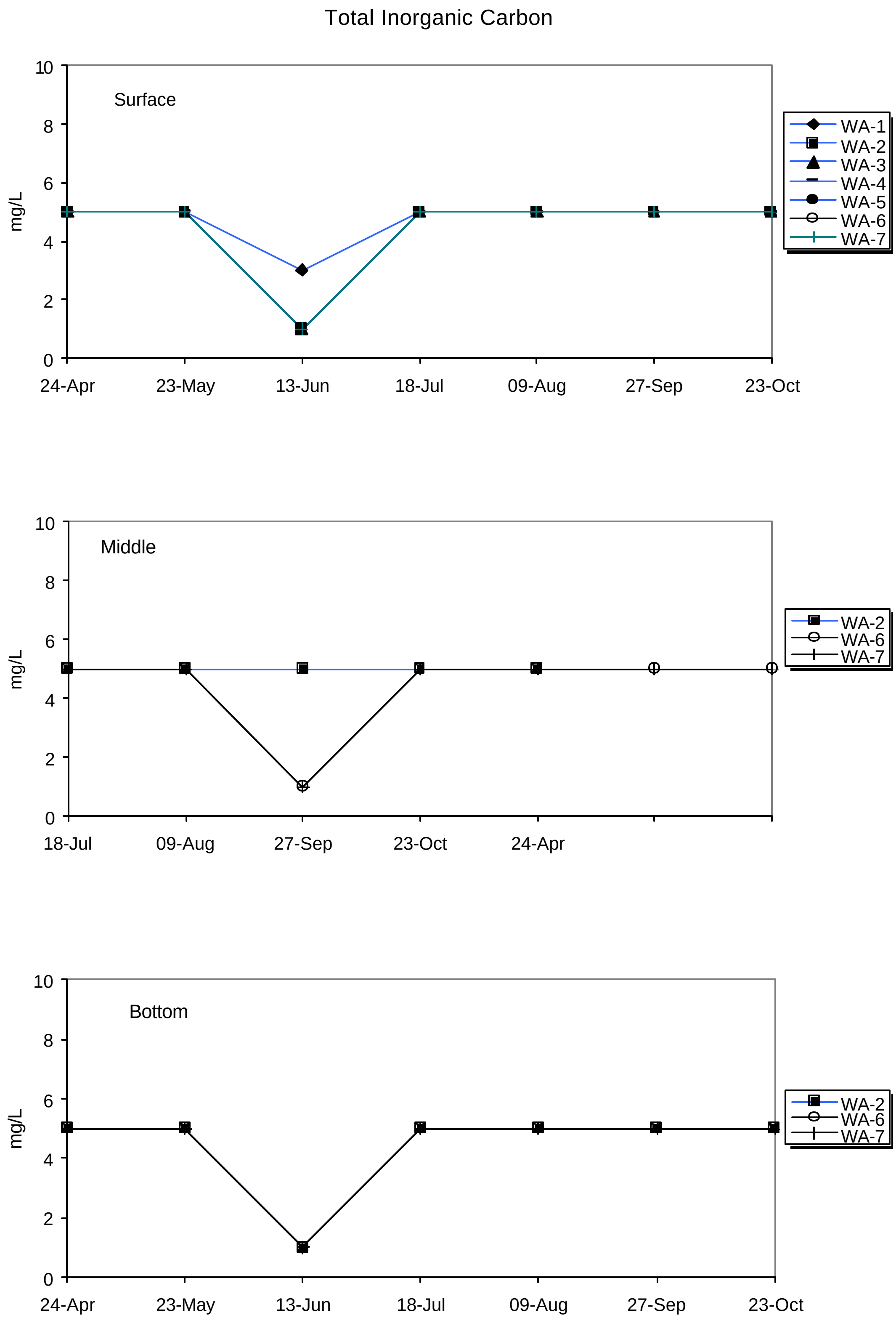

Figure 3-27. Total inorganic carbon measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2001.

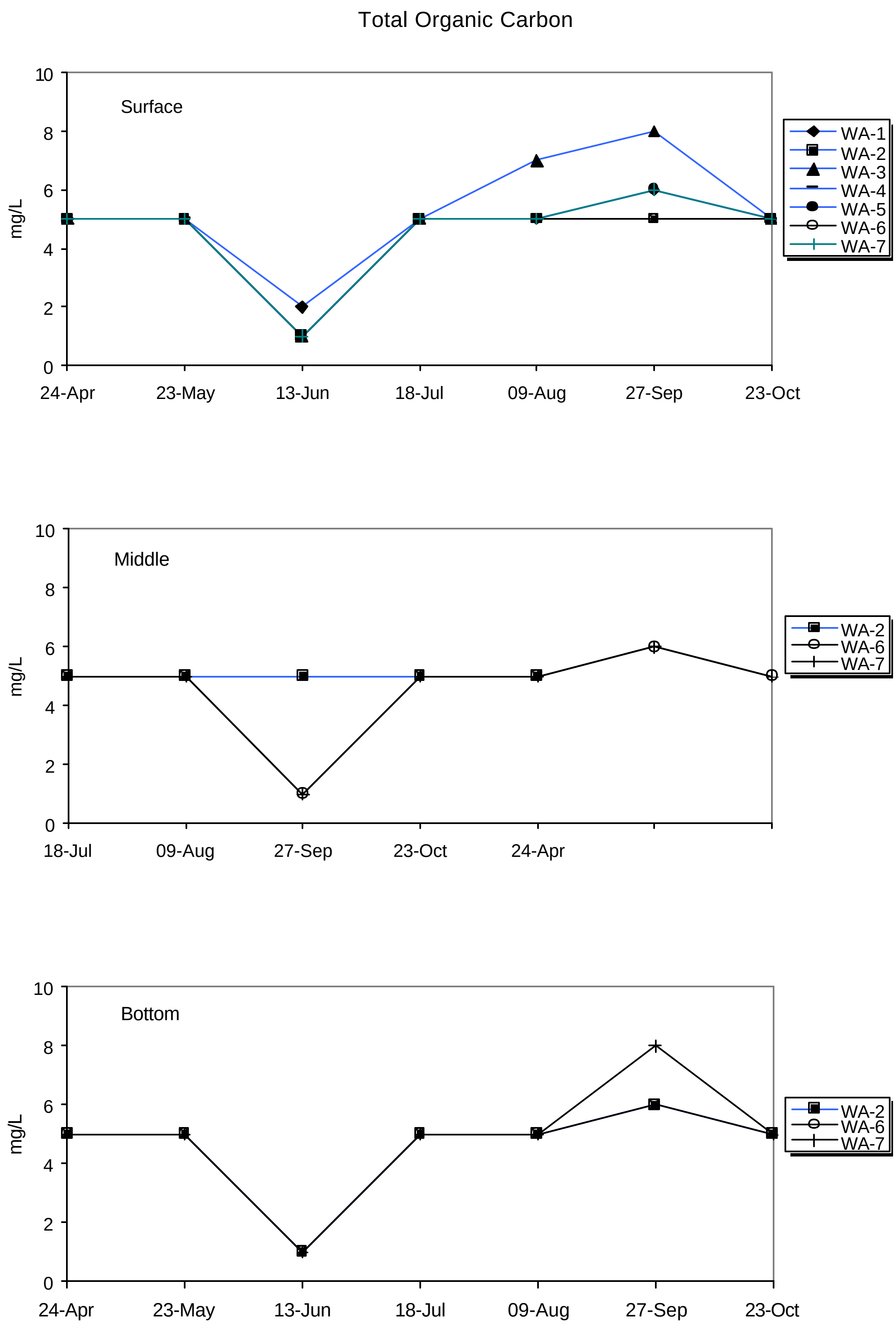

Figure 3-28. Total organic carbon measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2001

Chlorophyll *a*

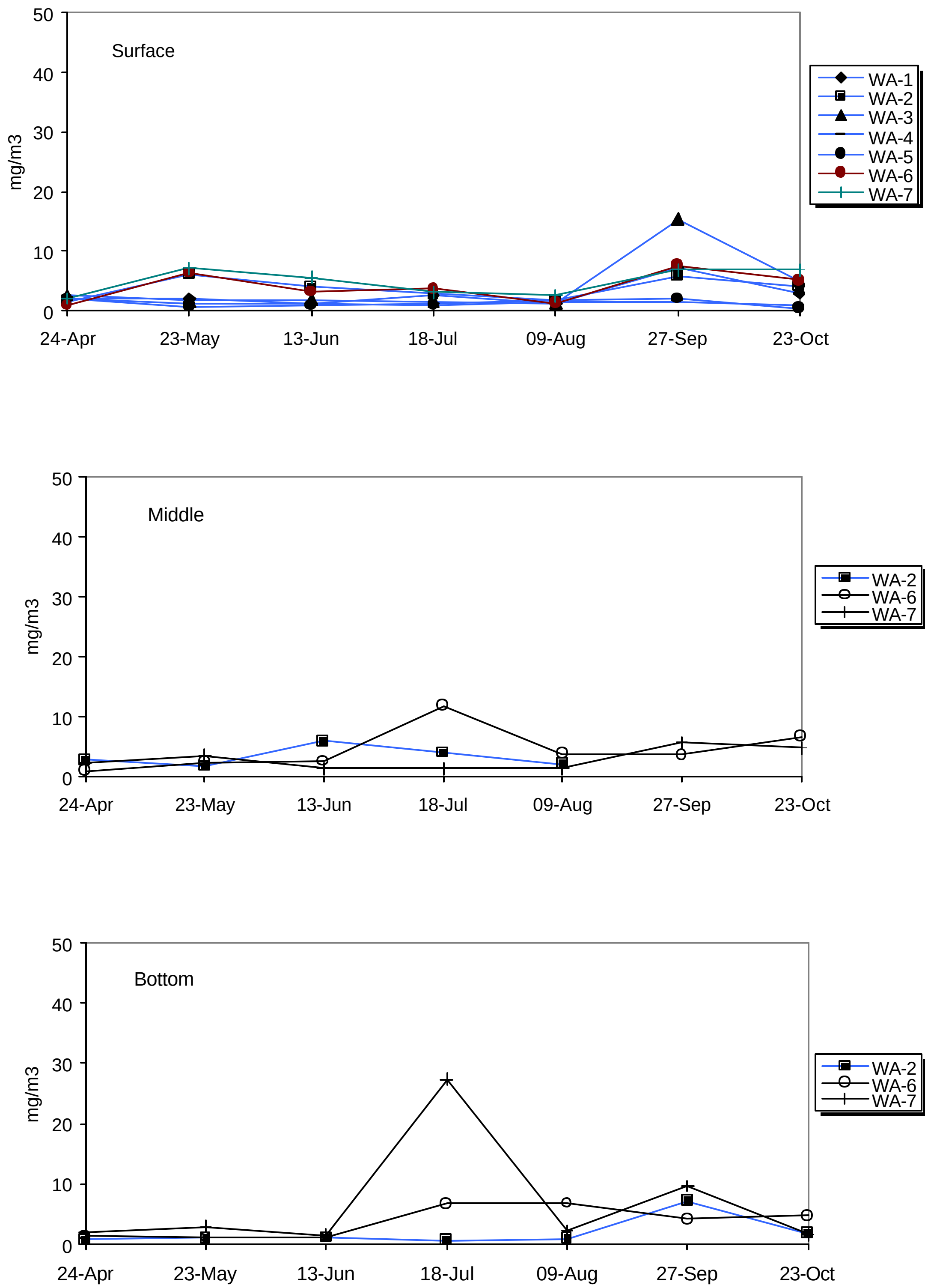

Figure 3-29. Chlorophyll *a* measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2001

TSIs calculated for measures of secchi disk depth classified F.E. Walter Reservoir as mesotrophic with values ranging from 40 to 47 in April through August. In September and October the trophic state is classified as mesoeutrophic with values of 51 and 55 (Fig. 3-30).

The TSI classification based on measures of total phosphorus was not feasible because of the high method detection limit for the parameter (Fig. 3-30). All concentrations measured at F.E. Walter Reservoir were less than the method detection limit of 0.05-mg/L. However, at this concentration, the TSI result of 60 is already bordering on eutrophic.

TSIs calculated for measures of chlorophyll *a* classified F.E. Walter Reservoir as mesotrophic during 2001 (Fig. 3-30). Most of the values throughout the monitoring period range from 40 to 50 except for two monthly averages in April and August, which range below 40 in the oligotrophic level.

Carlson (1977) warned against averaging TSI values estimated for different parameters, and instead suggested giving priority to chlorophyll *a* during the summer and to phosphorus in the spring, fall, and winter. With this in mind, and the general agreement in pattern between TSI values for secchi disk depth and chlorophyll *a*, it is our estimation that the reservoir was mesotrophic during 2001.

The EPA (1983) also provides criteria for classifying the trophic conditions of lakes of the North Temperate Zone based on concentrations of total phosphorus, chlorophyll *a*, and secchi disk depth (Table 3-9). As related above, total phosphorus was not measured with enough precision to permit a substantive interpretation of trophic condition. Of the remaining two parameters, the classifications of chlorophyll *a* and secchi disk depth classified the reservoir as mesotrophic. Following the logic of Carlson, and giving weight to chlorophyll *a*, the trophic state for F. E. Walter Reservoir during 2001 would be mesotrophic.

Table 3-9. EPA trophic classification criteria and average monthly measures for F.E. Walter Reservoir in 2001

Water Quality Variable	Oligo-trophic	Meso-trophic	Eutrophic	Apr	May	Jun	Jul	Aug	Sep	Oct
Total phos. (µg/l)	<10	10-20	>20	50	50	50	50	50	50	50
Chlorophyll (mg/m^3)	<4	4-10	>10	1.56	6.13	3.97	2.80	1.74	5.87	3.99
Secchi depth (m)	>3.7	2-4	<2	2.95	2.40	2.53	2.74	3.96	1.35	1.85

NM = not measured

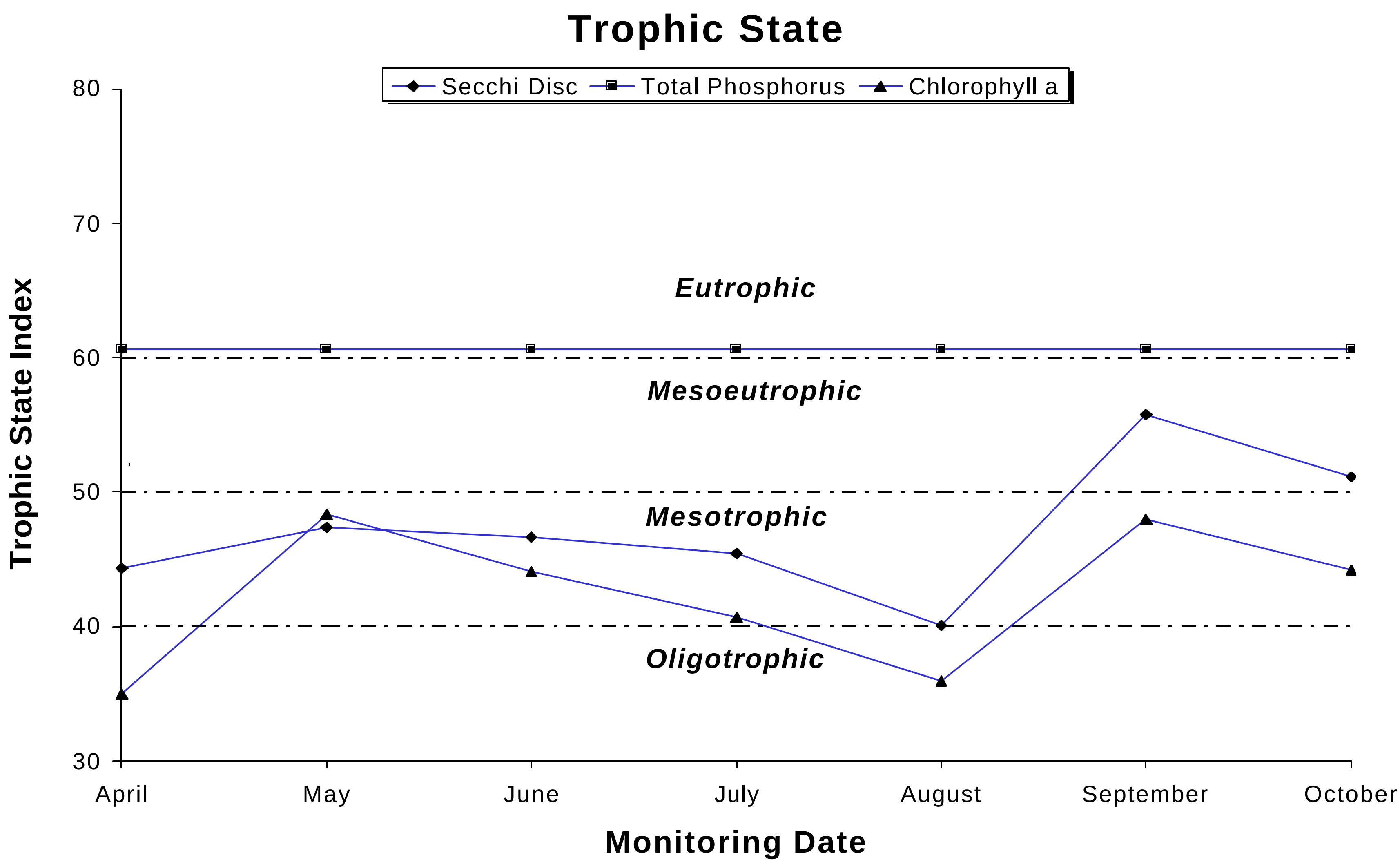

Figure 3-30. Trophic state indices calculated from secchi disk depth and concentrations of chlorophyll *a* and total phosphorus measured in surface water of F.E. Walter Reservoir during 2001

3.4 RESERVOIR BACTERIA MONITORING

Two forms of coliform bacteria contamination were monitored at F.E. Walter Reservoir during 2001 including total and fecal coliform (Table 3-10). Total coliform includes *Escherica coli* (*E. coli*) and related bacteria that are associated with fecal discharges. Fecal coliform bacteria are a subgroup of the total coliform and are normally associated with waste derived from human and other warm-blooded animals.

Total coliform contamination was variable at F.E. Walter Reservoir during 2001. Most counts among all stations ranged from 10 to 1500-clns/100-ml throughout the monitoring period (Table 3-10; Fig. 3-31). Coliform bacteria contamination counts were the highest in September and October at each station. Total coliforms were not detected at WA-1 and WA-6 in the June 2001 samples.

Fecal coliform contamination at F.E. Walter Reservoir during 2001 ranged from 10 to 800-clns/100-ml throughout the monitoring period (Table 3-10; Fig. 3-32). As was the case for total coliform, the highest fecal coliform levels were observed in September and October.

Bacteria contamination was high in September at F.E. Walter Reservoir with respect to PADEP water quality standards. The water quality standard for bacteria contamination is a geometric mean among fecal coliform samples less than 200 colonies/100-ml. However, application of this standard is conservative because swimming and other human/water contact recreation is prohibited in the reservoir. The geometric mean calculated in September among seven samples was 357.2–clns/100mls (Table 3-11; Fig. 3-33). The other months were below PADEP water quality standard.

Flow data from USGS gauging stations within the F. E. Walter Reservoir watershed (Stoddartsville and Blakeslee) were analyzed to qualitatively correlate precipitation events with coliform bacteria data (Fig 2-2 through 2-5). Precipitation may have contributed to elevated coliform levels in the reservoir. On 24 September, a storm event that exceeded two inches immediately preceeded monthly monitoring.

Fecal coliform counts for 2001 and historical data from the past 21 years were analyzed for seasonal trends. The trend analysis was conducted for spring and summer seasons separately for stations representative of the reservoir and downstream (Figs. 3-34 and 3-35). From the analysis, fecal coliform contamination appears to have increased downstream of the reservoir during the summer season. The increasing trend was significant (R^2=0.51; $P<0.001$), and appeared to be driven by high average counts (about 200 colonies/100-ml) from 1996 to present (Fig. 3-35). Significant trends were not determined for the reservoir in either season, or downstream of the reservoir for the spring (Fig. 3-36).

Table 3-10. Bacteria counts (colonies/100 ml) at F.E. Walter Reservoir during 2001.

Station	Date	Total Coliform (TC)	Fecal Coliform (FC)
WA-1S	24-Apr	130	10
	23-May	240	10
	13-Jun	< 10	< 10
	18-Jul	20	10
	9-Aug	30	20
	27-Sep	580	360
	23-Oct	320	100
WA-2S	24-Apr	310	< 10
	23-May	50	10
	13-Jun	300	20
	18-Jul	20	20
	9-Aug	70	10
	27-Sep	1200	40
	23-Oct	400	50
WA-3S	24-Apr	250	10
	23-May	100	50
	13-Jun	700	50
	18-Jul	180	100
	9-Aug	40	20
	27-Sep	1000	400
	23-Oct	520	240
WA-4S	24-Apr	230	10
	23-May	200	150
	13-Jun	1200	80
	18-Jul	130	120
	9-Aug	70	60
	27-Sep	1500	800
	23-Oct	780	280
WA-5S	24-Apr	440	< 10
	23-May	150	140
	13-Jun	800	20
	18-Jul	280	160
	9-Aug	260	80
	27-Sep	1200	500
	23-Oct	900	350
WA-6S	24-Apr	140	< 10
	23-May	50	10
	13-Jun	< 10	< 10
	18-Jul	10	10
	9-Aug	20	20
	27-Sep	1240	460
	23-Oct	900	260

Table 3-10. (Continued)			
Station	**Date**	**Total Coliform (TC)**	**Fecal Coliform (FC)**
WA-7S	24-Apr	120	< 10
	23-May	50	10
	13-Jun	200	10
	18-Jul	80	30
	9-Aug	30	10
	27-Sep	750	700
	23-Oct	490	80

Table 3-11. Summary statistics of fecal coliform counts (colonies/100-ml) among all stations of F.E. Walter Reservoir during 2001. (PADEP water quality standard for fecal coliforms is a geometric mean not greater than 200 colonies/ 100-ml.)

Date	Geometric Mean	Arithmetic mean	Maximum Count
24-Apr	10.0	10.0	10.0
23-May	27.0	54.3	150.0
13-Jun	20.6	28.6	80.0
18-Jul	38.0	64.3	160.0
9-Aug	23.4	31.4	80.0
27-Sep	357.2	465.7	800.0
23-Oct	157.9	194.3	350.0

Seasonal trend analyses of total and fecal coliform bacteria were conducted for individual stations of F. E. Walter Reservoir, combining 2001 and historical data (Tables 3-12 and 3-13). The Mann-Kendall statistic was applied to station data collected over the past 19 years or more, separately for spring (April to June) and summer (July to September) seasons. Stations included in the analysis were representative of downstream (WA-1), within the main reservoir (WA-2), and upstream sources on Tobyhanna Creek (WA-3), Lehigh River (WA-4), and Bear Creek (WA-5).

Fecal coliform bacteria appeared to have increased during the summer season at two locations within the F. E. Walter Reservoir drainage area. Significant trends were determined for stations downstream (WA-1), upstream on the Lehigh River (WA-4), and Bear Creek (WA-5). The yearly rates of increase ranged from 2 to 4 colonies/100-ml (Table 3-12). Significant trends of total coliform contaminants were not indicated at any of the stations in either season.

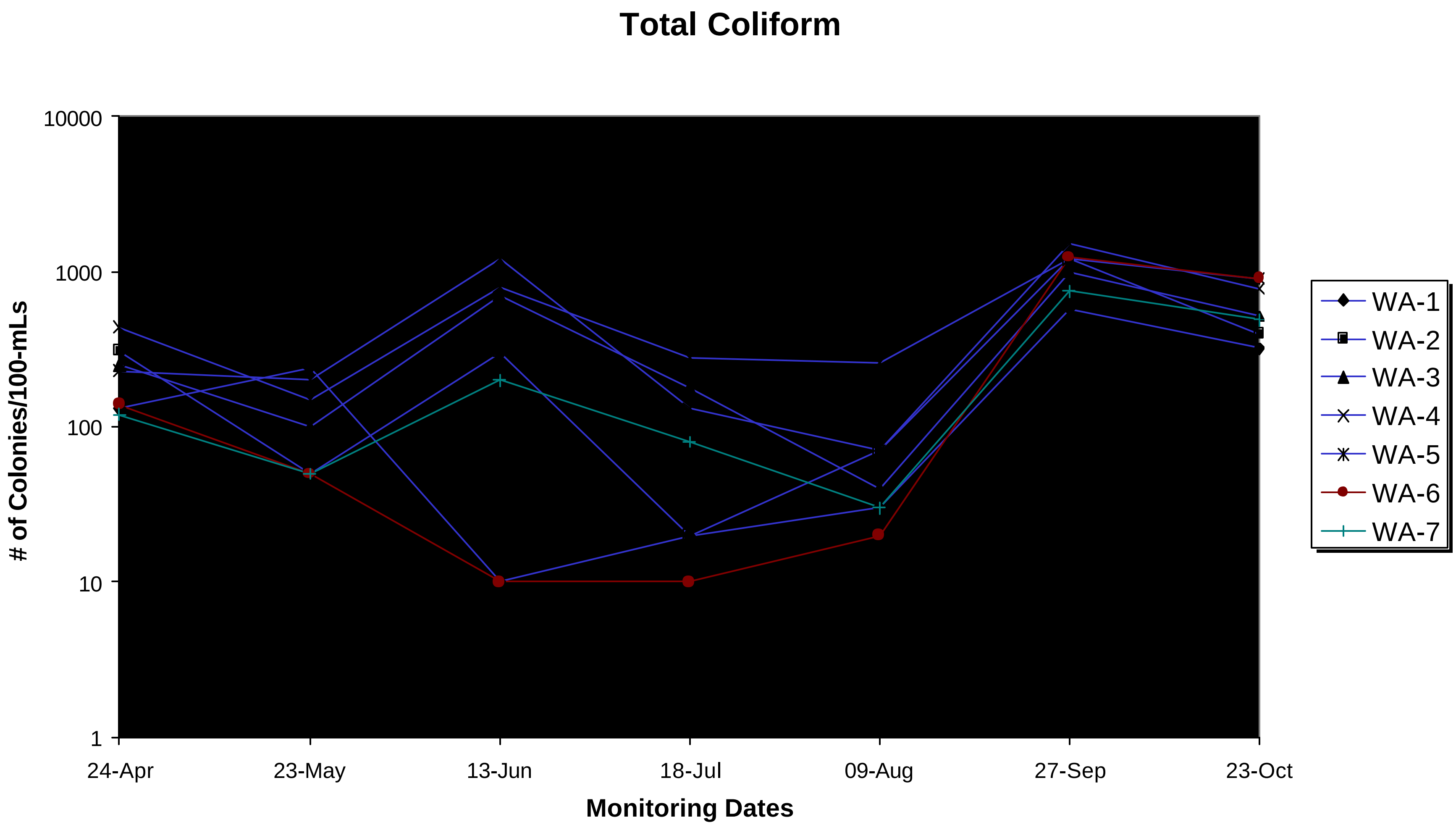

Figure 3-31. Counts of total coliform bacteria in surface waters of F.E. Walter Reservoir during 2001

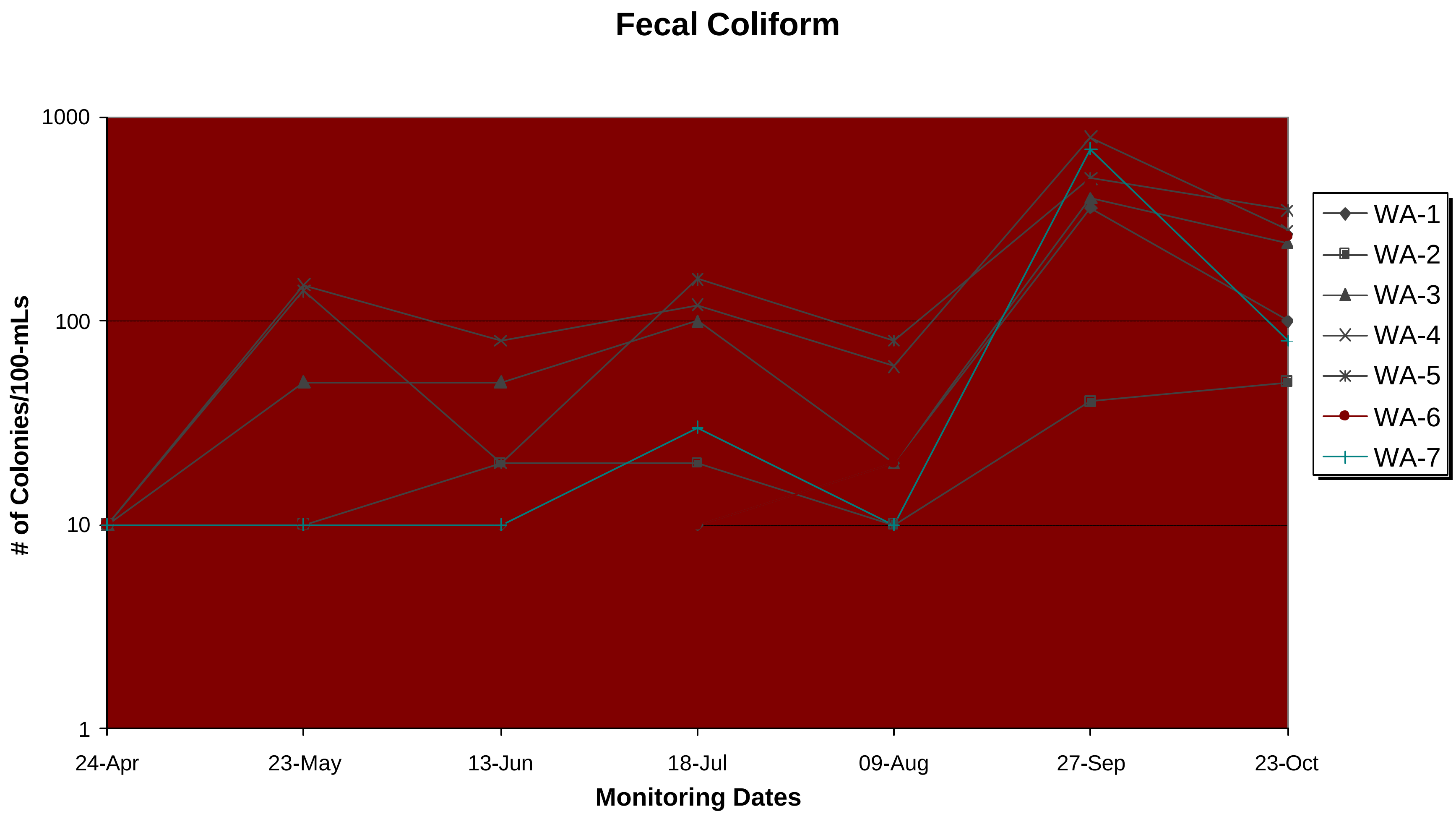

Figure 3-32. Counts of fecal coliform bacteria in surface waters of F.E. Walter Reservoir during 2001

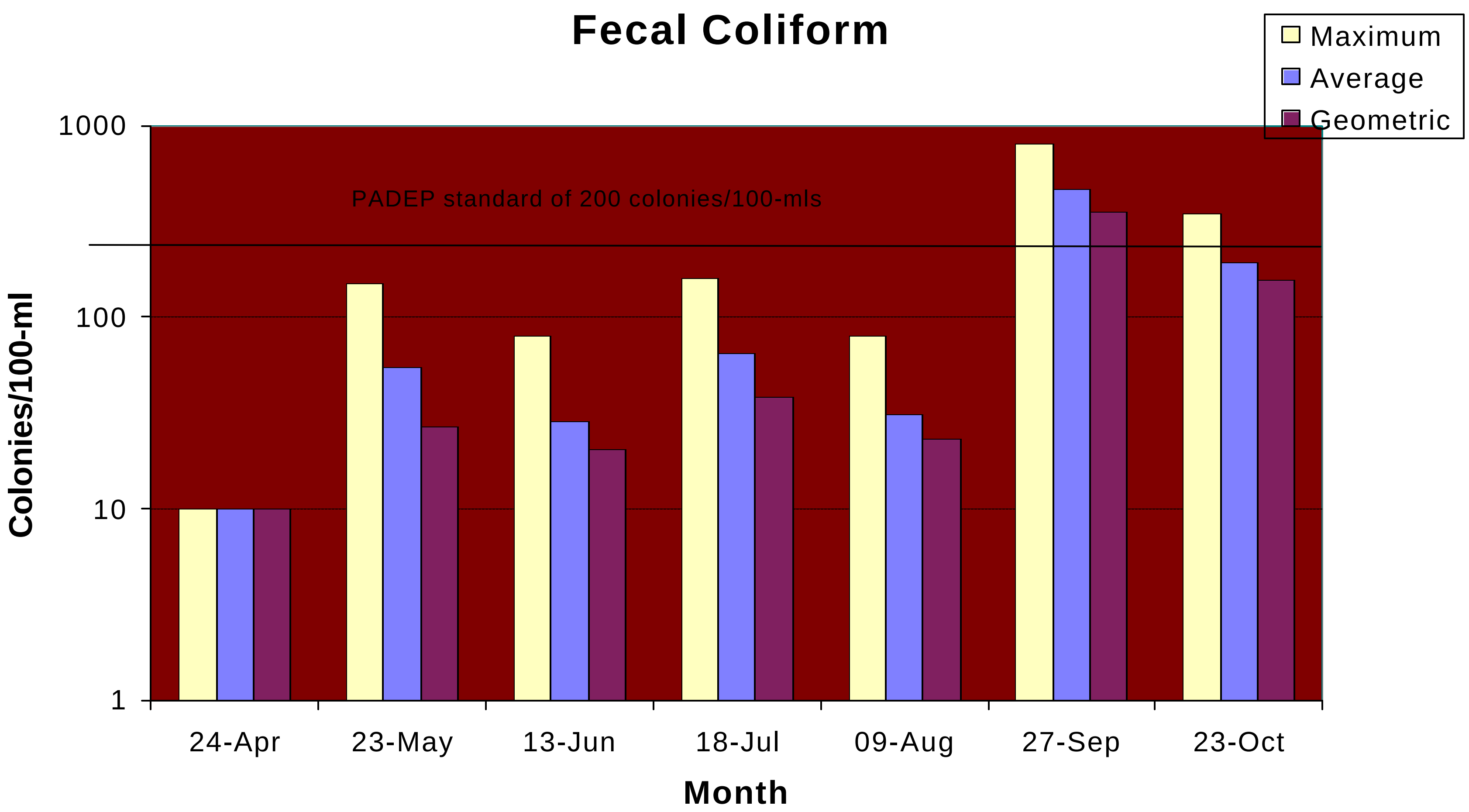

Figure 3-33. Maximum average, and geometric mean of fecal coliform counts (colonies/100-ml) for all stations monitored at F.E. Walter Reservoir in 2001

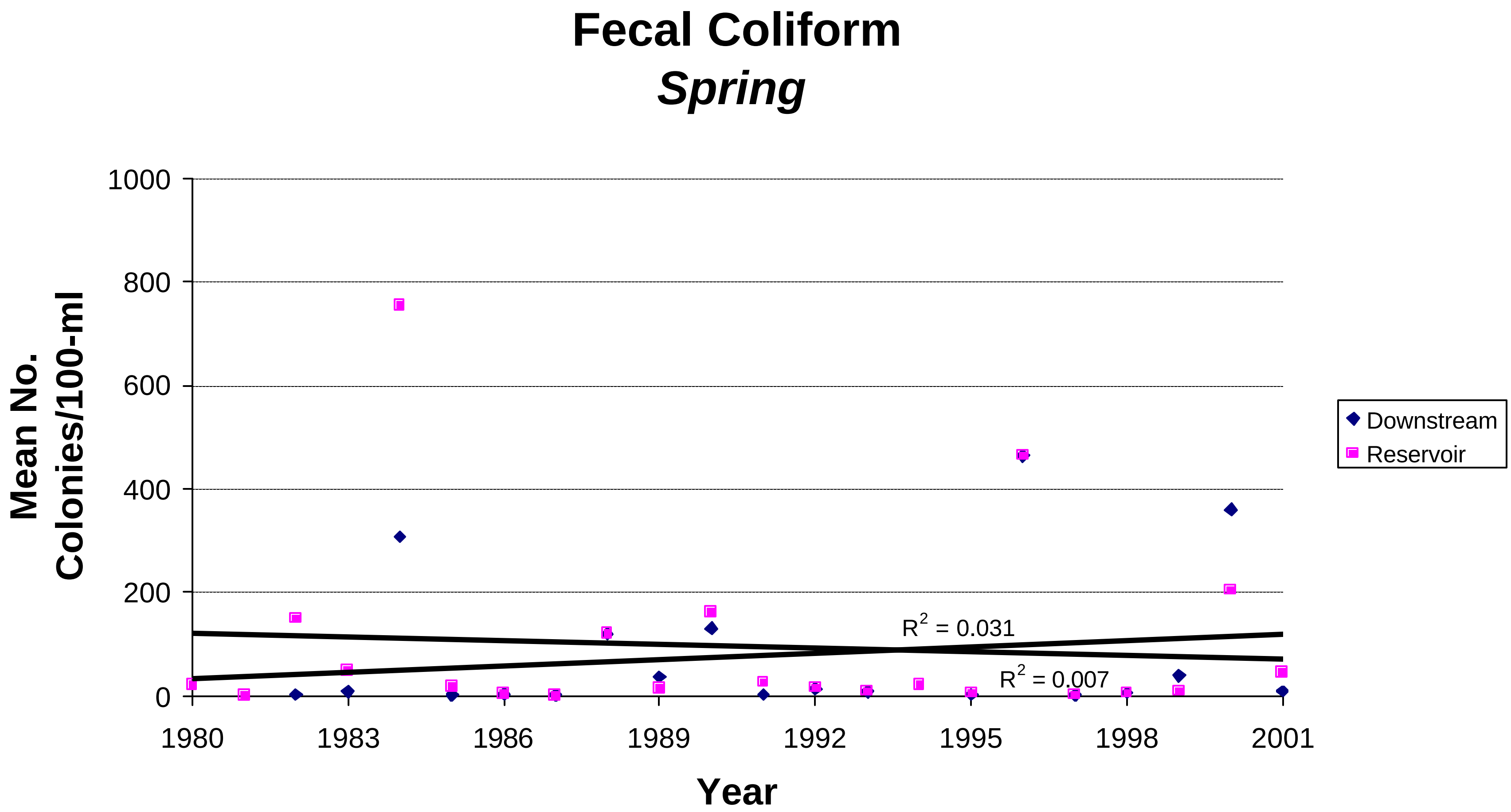

Figure 3-34. Seasonal trend analysis for counts of fecal coliform bacteria during spring months (Apirl, May, and June) at F.E. Walter Reservoir

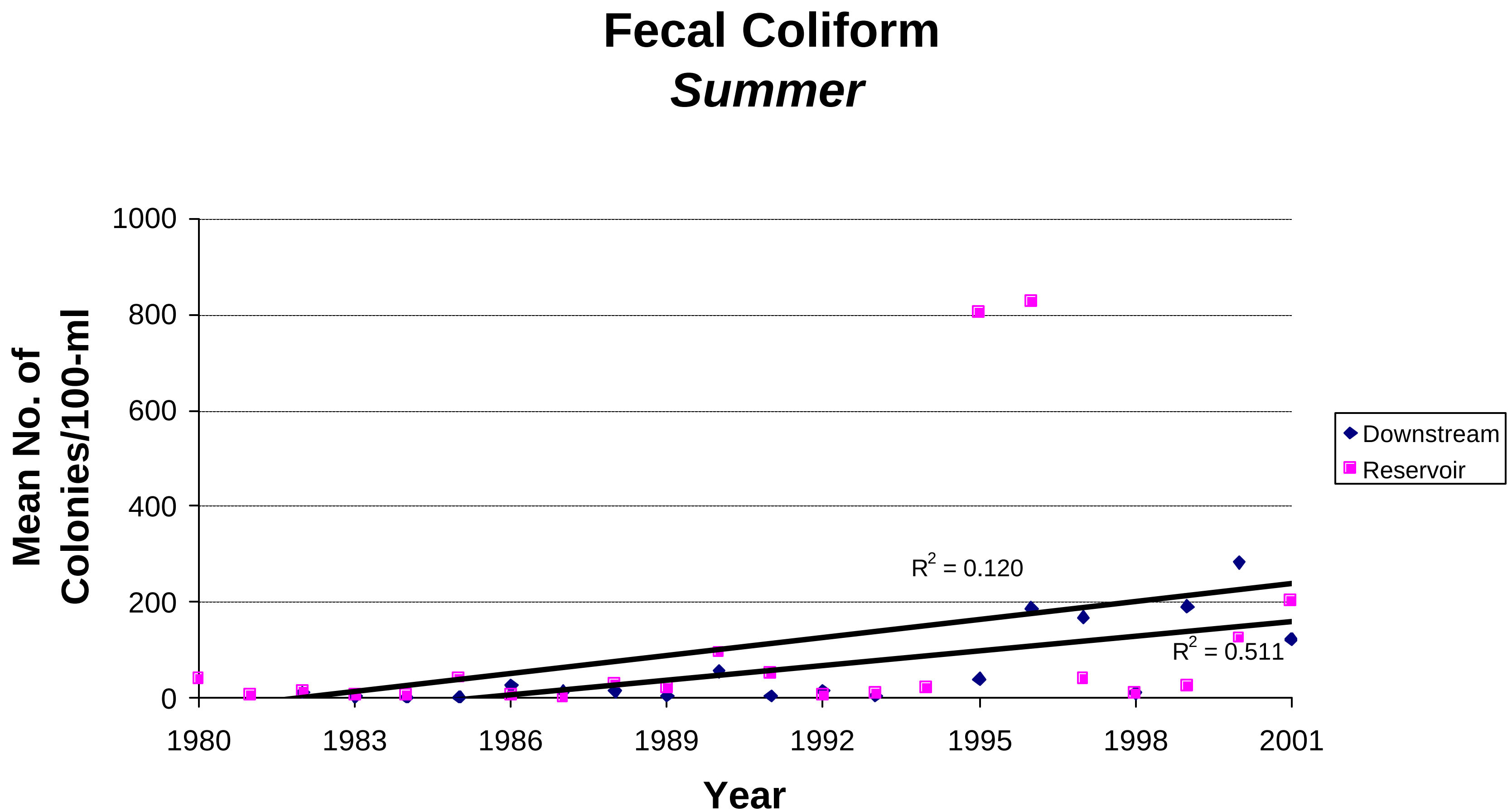

Figure 3-35. Seasonal trend analysis for counts of fecal coliform bacteria during summer months (July, August, and September) at F.E. Walter Reservoir

Table 3-12. Seasonal trends of fecal coliforms/100-ml at individual stations of F.E. Walter Reservoir calculated with the Mann-Kendall Statistic. Shaded values are significant at P=0.05.					
Station	# of Years spring/summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate
Surface Water					
WA-1	19	NS	0.300	<0.01	2.444
WA-2	22	NS	-0.944	NS	0.625
WA-3	22	NS	0.514	NS	3.00
WA-4	22	NS	2.611	<0.01	4.404
WA-5	22	NS	0.022	<0.05	2.163

Table 3-13. Seasonal trends of total coliforms/100-ml at individual stations of F.E. Walter Reservoir calculated with the Mann-Kendall Statistic.					
Station	# of Years spring/summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate
Surface Water					
WA-1	19	NS	-15.714	NS	6.00
WA-2	22	NS	-10.167	NS	0.278
WA-3	22/21	NS	-10.00	NS	11.448
WA-4	22	NS	10.188	NS	13.959
WA-5	22	NS	-2.205	NS	16.347

3.5 SEDIMENT PRIORITY POLLUTANT MONITORING

A sediment sample was collected at station WA-2 and analyzed for priority pollutant contaminants, Group 2 – semivolatile organic compounds and metals. Resulting concentrations were compared to New Jersey Soil Cleanup Criteria (NJDEP 1999; Table 3-14). The NJDEP criteria are human health based with categories addressing residential and non-residential settings, and impacts to groundwater. For our comparison, we reported the most conservative of the three criteria.

Of the 21 metals analyzed in F. E. Walter Reservoir sediments, only beryllium concentrations exceeded screening levels (Table 3-14). Beryllium exceeded the screening level by only 0.2 mg/kg.

A total of 17 semivolatile organics (SVOC) were analyzed in F. E. Walter Reservoir sediments (Table 3-16). None of the compounds were detected in the sediment sample from station WA-2 (Table 3-16).

Table 3-14. Metals and semivolaties (Group II) concentrations measured in sediments of F.E. Walter Reservoir in 2001. Shaded values indicate exceedances.

Parameter	Units	Method Detection Limit	WA-2	USACE Screening Level	References
CONVENTIONALS					
Percent Solids	%	0.1	25.2		
METALS					
Aluminum	mg/kg	80.2	10,983.80		
Antimony	mg/kg	1.6	ND	14	NJDEP 1999
Arsenic	mg/kg	4	ND	20	
Barium	mg/kg	0.4	144.3	700	NJDEP 1999
Beryllium	mg/kg	0.4	2.2	2	NJDEP 1999
Cadmium	mg/kg	0.4	4.9	39	NJDEP 1999
Calcium	mg/kg	1.6	2076.3		
Chromium	mg/kg	0.4	17.9	33	MacDonald 1992
Cobalt	mg/kg	1.6	16.6		
Copper	mg/kg	0.4	17.8	600	NJDEP 1999
Iron	mg/kg	20	21,885.50		
Lead	mg/kg	1.6	65.6	400	NJDEP 1999
Magnesium	mg/kg	1.6	1,555.20		
Manganese	mg/kg	0.4	735.9		
Mercury	mg/kg	0.07	0.07	0.1	MacDonald 1992
Nickel	mg/kg	0.4	32.1	250	NJDEP 1999
Potassium	mg/kg	1.6	738.3		
Selenium	mg/kg	4	ND	63	NJDEP 1999
Sodium	mg/kg	1.6	115.4		
Vanadium	mg/kg	1.6	23.5	370	NJDEP 1999
Zinc	mg/kg	0.4	424.9	1,500	NJDEP 1999

Table 3-14. (Continued)					
Parameter	**Units**	**Method Detection Limit**	**WA-2**	**USACE Screening Level**	**References**
SVOC (mg/kg)					
2,4,5-Trichlorophenol	mg/kg	0.397	ND	5,600	NJDEP 1999
2,4,6-Trichlorophenol	mg/kg	0.397	ND	62	NJDEP 1999
2,4-Dichlorophenol	mg/kg	0.397	ND	170	NJDEP 1999
2,4-Dimethylphenol	mg/kg	0.397	ND	10	NJDEP 1999
2,4-Dinitrophenol	mg/kg	0.397	ND	110	NJDEP 1999
2-Chlorophenol	mg/kg	0.397	ND	280	NJDEP 1999
2-Methylphenol	mg/kg	0.397	ND	2,800	NJDEP 1999
2-Nitrophenol	mg/kg	0.397	ND		
3-Methylphenol	mg/kg	0.397	ND		
4,6-Dinitro-2-methylphenol	mg/kg	0.397	ND		
4-Chloro-3-methylphenol	mg/kg	0.397	ND	10,000	NJDEP 1999
4-Methylphenol	mg/kg	0.397	ND	2,800	NJDEP 1999
4-Nitrophenol	mg/kg	0.397	ND		
Benzoic acid	mg/kg	0.397	ND		
Benzyl alcohol	mg/kg	0.397	ND	10,000	NJDEP 1999
Pentachlorophenol	mg/kg	0.397	ND	6	NJDEP 1999
Phenol	mg/kg	0.397	ND	10,000	NJDEP 1999

3.6 DRINKING WATER

Drinking water from the utility sink located in the maintenance building of F. E. Walter Reservoir was monitored for compliance with PADEP water quality standards for primary and secondary contaminants, and inorganic nitrogen (nitrate and nitrite) and coliform bacteria contaminants during 2001. Drinking water samples were analyzed in duplicate, comprising initial and confirmation samples. For matters of reporting, only if the result of the initial sample was not in compliance with water quality standards, the result of the confirmation sample was also reported.

3.6.1 Primary and Secondary Contaminants

F. E. Walter Reservoir drinking water was in compliance with PADEP water quality standards for all the primary and secondary contaminants with the exception of pH and manganese (Table 3-15). The initial and secondary samples for pH measurements were less than the standard range (6.5 to 8.5). The initial was 5.31 and the secondary was 5.4. The initial and secondary samples for manganese measured 0.053 mg/L. The PADEP regulatory level is 0.05 mg/L, therefore the concentration of manganese exceeded the regulatory level by a small amount of 0.003 mg/L. As part of drinking water compliance monitoring, Safe Drinking Water Act (SDWA) forms 4 for the reporting of results of primary and secondary drinking water contaminants were submitted to appropriate state environmental agencies.

Table 3-15. Concentrations of primary and secondary contaminants in drinking water at F.E. Walter Reservoir in 2001. Shaded values indicate results that exceeded Pennsylvania State drinking water standards; in these instances the result of a second sample is also reported.

Parameter	Sampling Date 14 June	PADEP Regulatory Level	Detection Limits	EPA Method
Aluminum	0.05	0.2	0.02	200.7
Antimony	ND	0.006	0.05	200.7
Arsenic	ND	0.05	0.05	200.7
Barium	0.010	2.0	0.005	200.7
Cadmium	ND	0.005	0.005	200.7
Chromium	ND	0.1	0.005	200.7
Copper	0.229	1.3	0.005	200.7
Iron	0.025	0.3	0.005	200.7
Lead	0.001	0.015	0.001	200.8
Magnesium	0.73	NL	0.02	200.7
Manganese	0.053	0.05	0.005	200.7
Mercury	ND	0.002	0.0002	245.1
Nickel	ND	0.1	0.005	200.7
Selenium	ND	0.05	0.05	200.7
Silver	ND	0.1	0.005	200.7
Sodium	0.30	NL	0.02	200.7
Thallium	ND	0.002	0.05	200.7
Zinc	0.015	5.0	0.005	200.7
Chloride	1	250	1	325.3
Cyanide	ND	0.2	0.007	SM 4500CN-C&E
Fluoride	ND	2.0	0.1	SM 4500F-C
Foaming Agents	ND	0.5	0.05	SM 5540C
PH	5.4	6.5-8.5	+/-0.01	150.1
Sulfate	7	250.0	5	375.4
Total Dissolved Solids	ND	500.0	10	SM 2540C

All results, criteria and detection limits are expressed in mg/L except pH which is expressed in positive/negative
ND – Not Detected
NL – Not Listed

3.6.2 Inorganic Nitrogen and Coliform Bacteria

F. E. Walter Reservoir drinking water was in compliance with PADEP criteria for inorganic nitrogen contaminants, nitrate and nitrite, and coliform bacteria contaminants (Table 3-16). None of these contaminants were found in the drinking waters samples at F.E. Walter

Reservoir. Following laboratory testing, drinking water monitoring results were recorded on Safe Drinking Water Act (SDWA-S and SDWA-4) forms and submitted to the appropriate state environmental agencies.

Table 3-16. Concentrations of nitrate and nitrite, and results of coliform bacteria monitoring of drinking water sampled from the public water fountain located in the overlook building at F.E. Walter Reservoir during 2001

Parameter	Sampling Dates			PADEP Regulatory Level	Detection Limits	Method
	14 June		9 August			
Nitrate as N (mg/L)	ND		ND	10.0	0.5	SM4500
Nitrite as N (mg/L)	ND		ND	1.0	0.5	SM4500
E. coli (CFU)	Absence	Absence	Absence	Presence	1	SM 9223
Total Coliform (CFU)	Absence	Absence	Absence	Presence	1	SM 9223

3.6.3 Historical Drinking Water Quality

Drinking water quality has been monitored at Blue Marsh Reservoir over the past 19 years. Versar (1996) compiled the results from all of the previous years into a single database to facilitate water quality comparisons. Historical data from drinking water quality parameters were compared to their respective PADEP standards. Of 26 parameters summarized, 4 had incidences of noncompliance with drinking water standards from 1983 to present (Table 3-17). Cadmium, Copper, pH and corrosivity were most often not in compliance with PADEP criteria. During 2001 monitoring period, manganese and pH were out of compliance.

Table 3-17. Drinking water parameters exceeding PADEP criteria at F.E. Walter Reservoir from 1983 to 2001

Parameter	Monitoring Date	Result	Criteria
Cadmium (mg/L)	15 June 1987	0.006	0.005
	26 July 1988	0.008	0.005
	4 April 1991	0.007	0.005
	27 July 1994	0.040	0.005
Copper (mg/L)	10 June 1998	2.83	1.3
	20 June 2000	2.03	1.3
Corrosivity	10 June 1998	-1.80	Non-negative
	22 June 1999	NEG	Non-negative
	20 June 2000	-5.3	Non-negative
pH	10 June 1998	5.9	6.5-8.5
	22 June 1999	5.6	6.5-8.5
	20 June 2000	5.5	6.5-8.5
	14 June 2001	5.4	6.5-8.5
Manganese	14 June 2001	0.053	0.05

4.0 SUMMARY

The USACE implements a yearly monitoring program at F. E. Walter Reservoir to evaluate potential public health concerns. In general, the monitoring programs emphasize measuring water quality and sediment contamination. Monitoring results are compared to state and federal criteria to evaluate the condition of F. E. Walter Reservoir. The 2001 monitoring program of F. E. Walter Reservoir comprised three major elements:

- monthly water quality monitoring of nutrient and organic contamination, bacteria levels, and physical/chemical conditions at fixed stations from April through October;
- sediment priority pollutant monitoring for semi volatile organic compounds and metals at one fixed station; and
- drinking water monitoring conducted at the water fountain in the operations building.

4.1 WATER QUALITY MONITORING

Water quality monitoring at F. E. Walter Reservoir generally indicated the presence of acceptable conditions during 2001. In general surface and downstream water quality were in compliance with the PADEP water quality standard, a minimum concentration of 5-mg/L. However, dissolved oxygen (DO) in the lower water column of the deeper portions of the reservoir was below standards at two stations in August. Measures of pH were within the water quality standard range from 6 to 9. F. E. Walter Reservoir contained acceptable levels of nutrients during 2001. Ammonia, nitrate + nitrite, TDS, and alkalinity were in compliance with state water quality standards throughout the reservoir watershed.

4.2 MONITORING PROGRAM TRENDS

Trends computed for individual stations using the Mann-Kendall test indicated significant water quality changes at several locations in the F. E. Walter Reservoir drainage. Ammonia was decreasing in the reservoir watershed in both spring and summer seasons. Station WA-1, -2, and -3 all had decreasing trends for total nitrogen. Trends for fecal coliform were increasing during the summer at upstream stations, WA-4 and WA-5, as well as downstream of the reservoir at station WA-1. Trends for total phosphorus, TDS, BOD, and total coliform were not significant.

4.3 TROPHIC STATE CLASSIFICATION

The trophic condition of F.E. Walter Reservoir was characterized as mesotrophic in 2001. The trophic status was defined independently by Carlson's trophic state indices and EPA criteria. Both classifications were based on concentrations of chlorophyll *a* and secchi disk depths.

4.4 COLIFORM BACTERIA MONITORING

Coliform bacteria contamination at F. E. Walter Reservoir was generally acceptable during 2001. However, the geometric means during September monitoring was higher than the PADEP water quality standards of 200 colonies/100-ml. Both regression and Mann-Kendall analyses indicated an increasing trend for fecal coliform downstream of the reservoir during summer. The Mann-Kendall also determined an increasing trend upstream on the Lehigh River (WA-4) for fecal coliform during the summer.

4.5 SEDIMENT PRIORITY POLLUTANT MONITORING

F.E. Walter Reservoir was in compliance with NJDEP soil guidelines in 2001. Concentrations of most metals and semivolatile organic compounds were less than screening guidelines. Only beryllium exceeded the NJDEP soil guidelines.

4.6 DRINKING WATER MONITORING

F. E. Walter Reservoir drinking water was in compliance with PADEP drinking water standards for primary and secondary and bacteria with the exception of pH and manganese. Manganese concentration of 0.053 mg/L exceeded the PADEP drinking water standards by 0.003 mg/L. Measures of pH were less than the standard range of 6.5 to 8.5.

5.0 RECOMMENDATIONS

The USACE intends to continue monitoring of the F.E. Walter Reservoir in future years to evaluate trends and to identify potential environmental problems related to human development within the watershed. The USACE is continually seeking to improve the quality and cost-effectiveness of the information gathered as part of this effort. Below, we present three recommendations for improving the monitoring program:

Recommendation 1: Add a monitoring component to assess relative loadings of nutrients, toxic chemicals and sediment from each of the major watersheds draining into the F.E. Walter Reservoir.

The F.E. Walter Reservoir contains several feeder streams, which drain different watersheds. Each of these watersheds has different land use characteristics (e.g., residential, agricultural, forested ecosystems) each of which may contribute a different suite of chemical loadings to the reservoir. Management of water quality problems in the reservoir will require an understanding of the relative loadings of nutrients, toxics, and sediment from each watershed, and in which watersheds these loadings are changing most rapidly. Developing this information could be accomplished by deploying automatic samplers into the major feeder streams to obtain composite samples over randomly selected 24-hour periods, stratified by season, and by conducting special sampling during storm events.

Recommendation 2: Adjust nutrient concentration to account for yearly differences in flow.

The trends presented in this report have not taken into account the effects of flow volume on parameter concentrations. Further analyses using concentrations weighted for stream flow (from USGS gauging stations) would provide a better estimate of trends within the system. These data could be used to calculate total nutrient loadings (kg/day) and could form the basis for creating a nutrient budget for the system. The observed trends should be correlated to management practices in the watershed (e.g., sewage treatment plant construction or upgrades, changes in agricultural activities) to help explain water quality improvements or degradations observed during the monitoring period.

Recommendation 3: Conduct a watershed modeling effort.

A survey of all nutrient and pollutant sources (point source and non-point source) within the F.E. Walter Reservoir watershed could be conducted and presented in a GIS format. Using predicted loadings from the various pollutant sources identified within the watershed, a simple nutrient/DO prediction model could be constructed and verified with the long-term data set. This model could be used to predict the degree of improvement in reservoir water quality that could be obtained through various nutrient control measures such as sewage treatment upgrades and reduced fertilizer application to farmlands.

6.0 REFERENCES

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APPENDIX A

STRATIFICATION MONITORING

Table A-1. Summary of stratification monitoring at F.E. Walters Reservoir in 2001

Station	Date	Depth (F)	Temp ?C	pH	DO(mg/L)	DO (%)	Cond (mS/Cm)
WA1	24-Apr	0	13.74	7.50	*	*	0.08
	23-May	0	14.65	7.72	9.49	93.42	0.08
	13-Jun	0	18.11	8.22	8.72	92.33	0.08
	18-Jul	0	20.61	6.35	17.29	192.50	0.07
	09-Aug	0	23.72	6.63	8.03	94.92	0.09
	27-Sep	0	15.23	7.04	9.13	91.01	0.09
	23-Oct	0	10.90	7.36	9.14	82.80	0.09
WA2	24-Apr	40	9.56	7.19	*	*	0.08
		35	11.40	7.16	*	*	0.08
		30	13.03	7.17	*	*	0.08
		25	13.27	7.15	*	*	0.08
		20	13.57	7.13	*	*	0.08
		15	14.32	7.14	*	*	0.08
		10	14.87	7.14	*	*	0.08
		5	15.11	7.14	*	*	0.08
		0	15.35	7.11	*	*	0.08
	23-May	40	14.00	8.20	8.80	85.41	0.08
		35	14.09	7.98	8.70	84.60	0.08
		30	14.19	7.92	8.64	84.20	0.08
		25	14.32	7.88	8.70	85.03	0.08
		20	14.58	7.84	8.59	84.43	0.08
		15	15.92	7.74	8.45	85.48	0.08
		10	16.24	7.72	8.80	89.62	0.08
		5	16.32	7.71	8.77	89.47	0.08
		0	16.33	7.70	8.86	90.41	0.08
	13-Jun	35	17.16	7.71	7.24	75.17	0.08
		30	17.36	7.62	7.41	77.26	0.08
		25	17.92	7.54	7.37	77.73	0.08
		20	18.21	7.51	7.47	79.26	0.08
		15	19.08	7.41	7.44	80.35	0.08
		10	19.82	7.32	7.97	87.36	0.08
		5	23.43	7.31	8.15	95.81	0.08
		0	23.97	7.32	8.03	95.37	0.08
	18-Jul	30	20.15	6.24	6.70	73.92	0.08
		25	20.66	6.27	6.90	76.90	0.07
		20	21.00	6.33	6.75	75.73	0.07
		15	21.54	6.39	7.39	83.79	0.07
		10	22.01	6.50	7.58	86.73	0.07
		5	23.94	6.65	7.53	89.38	0.07
		0	24.44	6.75	9.98	119.57	0.07

Table A-1. (Continued)

Station	Date	Depth (F)	Temp ?C	pH	DO(mg/L)	DO (%)	Cond (mS/Cm)
WA2 (Con't)	09-Aug	45	22.87	6.30	3.93	45.72	0.09
		40	22.96	6.21	4.89	56.98	0.09
		35	23.14	6.18	5.03	58.81	0.09
		30	23.56	6.26	5.81	68.47	0.09
		25	24.11	6.44	6.71	79.90	0.08
		20	24.53	6.58	7.35	88.21	0.08
		15	25.24	6.65	7.19	87.43	0.08
		10	25.86	6.73	7.54	92.73	0.08
		5	27.63	6.78	7.06	89.64	0.09
		0	28.11	6.81	7.19	92.07	0.09
	27-Sep	50	14.13	6.85	7.72	75.14	0.09
		45	14.24	6.86	7.59	74.05	0.09
		40	14.41	6.81	7.44	72.86	0.09
		35	14.72	6.78	7.30	71.97	0.09
		30	14.85	6.83	7.06	69.80	0.09
		25	14.88	6.84	7.13	70.54	0.09
		20	15.27	6.84	7.40	73.83	0.09
		15	15.68	6.87	7.37	74.18	0.09
		10	16.18	6.91	7.34	74.66	0.09
		5	16.94	6.93	7.28	75.24	0.09
		0	16.98	6.96	7.82	80.89	0.09
	23-Oct	35	10.36	7.08	8.12	72.60	0.09
		30	10.67	7.01	8.09	72.80	0.09
		25	11.19	6.98	8.00	72.90	0.09
		20	11.30	6.96	8.04	73.50	0.09
		15	11.47	6.96	7.92	72.60	0.09
		10	11.51	6.94	8.06	73.90	0.09
		5	11.63	6.94	8.15	75.00	0.09
		0	11.86	6.96	8.42	77.9	0.09
WA3	24-Apr	0	13.47	7.56	*	*	0.12
	23-May	0	14.17	8.06	9.95	96.9	0.09
	13-Jun	0	19.17	7.18	9.51	102.9	0.09
	18-Jul	0	19.02	6.78	14.61	157.6	0.09
	09-Aug	0	21.90	7.15	8.32	95.0	0.09
	27-Sep	0	15.09	7.05	9.42	93.6	0.09
	23-Oct	0	12.53	7.26	10.07	94.6	0.09
WA4	24-Apr	0	16.11	7.55	*	*	0.07
	23-May	0	13.52	8.25	10.23	98.2	0.08
	13-Jun	0	19.56	8.20	9.48	103.4	0.07
	18-Jul	0	19.82	7.07	8.79	96.3	0.07
	09-Aug	0	22.80	7.21	8.41	97.7	0.09
	27-Sep	0	11.60	6.92	8.50	78.2	0.10
	23-Oct	0	12.91	7.24	11.04	104.6	0.08

Table A-1. (Continued)

Station	Date	Depth (F)	Temp ?C	pH	DO(mg/L)	DO (%)	Cond (mS/Cm)
WA5	24-Apr	0	15.00	6.83	*	*	0.09
	23-May	0	13.00	8.24	9.78	92.9	0.14
	13-Jun	0	18.29	8.22	8.34	88.6	0.07
	18-Jul	0	19.29	6.29	7.08	76.8	0.08
	09-Aug	0	23.93	6.49	5.74	68.1	0.12
	27-Sep	0	11.06	6.20	8.57	77.9	0.10
	23-Oct	0	12.50	7.32	8.25	77.5	0.10
WA6	24-Apr	20	14.11	6.61	*	*	0.08
		15	14.78	6.59	*	*	0.08
		10	15.43	6.60	*	*	0.08
		5	15.91	6.61	*	*	0.08
		0	16.82	6.65	*	*	0.08
	23-May	25	14.47	8.39	8.75	85.8	0.08
		20	14.72	7.87	8.76	86.4	0.08
		15	15.27	7.83	8.81	87.9	0.08
		10	15.59	7.78	8.84	88.8	0.08
		5	16.40	7.72	8.81	90.0	0.08
		0	16.45	7.70	9.45	96.7	0.08
	13-Jun	25	18.08	7.70	7.70	81.5	0.07
		20	18.43	7.64	7.73	82.4	0.07
		15	19.21	7.57	7.83	84.8	0.07
		10	20.17	7.51	8.05	88.9	0.07
		5	21.36	7.40	8.27	93.4	0.08
		0	22.96	7.40	8.27	96.4	0.08
	18-Jul	20	21.31	6.47	8.49	95.8	0.07
		15	21.51	6.55	8.39	95.1	0.07
		10	22.06	6.64	7.95	91.0	0.07
		5	23.49	6.74	8.06	94.9	0.07
		0	24.02	6.79	7.76	92.2	0.07
	09-Aug	20	24.34	6.59	6.32	75.6	0.09
		15	25.29	6.67	6.64	80.8	0.09
		10	26.21	6.56	6.67	82.6	0.09
		5	27.61	6.76	6.57	83.4	0.09
		0	28.21	6.85	6.78	87.0	0.09
	27-Sep	25	15.37	6.75	7.74	77.4	0.09
		20	15.77	6.79	7.49	75.5	0.09
		15	16.21	6.83	7.20	73.3	0.09
		10	16.64	6.86	7.25	74.5	0.09
		5	17.12	6.94	7.48	77.6	0.09
		0	17.10	6.98	8.07	83.7	0.09

Table A-1. (Continued)

Station	Date	Depth (F)	Temp ?C	pH	DO(mg/L)	DO (%)	Cond (mS/Cm)
WA6 (Con't)	23-Oct	20	12.02	7.28	8.36	77.6	0.09
		15	12.11	7.26	8.49	79.0	0.09
		10	12.09	7.12	8.48	78.9	0.09
		5	12.10	7.18	8.56	79.7	0.09
		0	12.11	7.18	8.79	81.8	0.09
WA7	24-Apr	20	15.14	6.75	*	*	0.08
		15	15.58	6.76	*	*	0.08
		10	15.70	6.76	*	*	0.08
		5	15.80	6.76	*	*	0.08
		0	15.79	6.78	*	*	0.08
	23-May	20	14.50	8.34	9.11	89.4	0.08
		15	15.12	7.95	8.85	88.0	0.08
		10	15.88	7.89	8.70	87.9	0.08
		5	16.39	7.83	8.70	88.9	0.08
		0	16.41	7.83	8.90	91.0	0.08
	13-Jun	25	17.55	7.71	6.74	70.5	0.08
		20	18.40	7.64	6.96	74.1	0.08
		15	19.00	7.57	7.26	78.3	0.08
		10	19.77	7.52	7.20	78.8	0.08
		5	21.78	7.46	7.92	90.2	0.08
		0	23.19	7.43	7.73	90.5	0.08
	18-Jul	22	20.26	6.80	8.89	98.3	0.08
		20	20.75	6.61	7.55	84.3	0.07
		15	21.31	6.56	7.69	86.8	0.07
		10	21.82	6.70	7.95	90.6	0.07
		5	22.68	6.91	8.37	97.0	0.07
		0	23.95	6.89	8.10	96.2	0.07
	09-Aug	25	23.63	6.28	3.40	40.1	0.09
		20	24.20	6.41	5.84	69.7	0.09
		15	25.41	6.59	6.51	79.4	0.09
		10	26.90	6.72	7.15	89.6	0.09
		5	27.78	6.91	7.24	92.2	0.09
		0	28.33	6.94	7.26	93.3	0.09
	27-Sep	25	13.45	6.97	8.13	78.0	0.09
		20	14.10	6.99	7.75	75.4	0.09
		15	16.14	7.00	7.49	76.1	0.09
		10	16.86	6.98	7.45	76.9	0.09
		5	16.93	6.99	7.41	76.6	0.09
		0	16.93	7.02	7.93	81.9	0.09

Table A-1. (Continued)

Station	Date	Depth (F)	Temp ?C	pH	DO(mg/L)	DO (%)	Cond (mS/Cm)
WA7 (Con't)	23-Oct	21	10.63	7.15	8.25	74.2	0.09
		15	11.63	7.12	8.35	76.8	0.09
		10	11.90	7.14	8.30	76.9	0.09
		5	11.94	7.12	8.42	78.0	0.09
		0	12.20	7.16	8.69	81.0	0.09

* Dissolved Oxygen was not sampled in April due to a probe malfunction

APPENDIX B

WATER COLUMN CHEMISTRY MONITORING LABORATORY ANALYSIS CERTIFICATES

APPENDIX C

SEDIMENT PRIORITY POLLUTANT AND ARSENIC MONITORING LABORATORY ANALYSIS CERTIFICATES

APPENDIX D

DRINKING WATER MONITORING LABORATORY ANALYSIS CERTIFICATES

APPENDIX E

SCOPE OF WORK